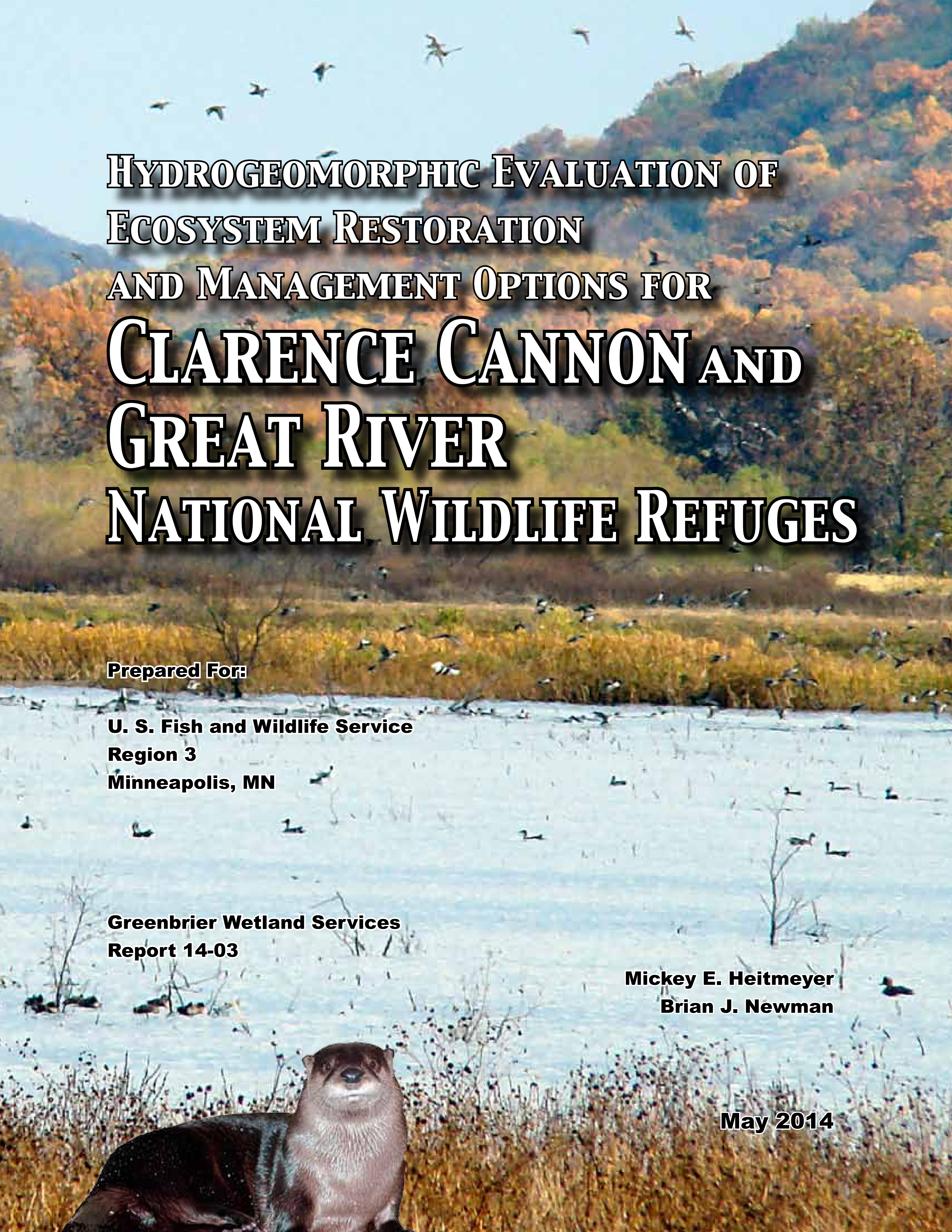

Hydrogeomorphic Evaluation of Ecosystem Restoration and Management Options for Clarence Cannon and Great River National Wildlife Refuges

Prepared For:

U. S. Fish and Wildlife Service
Region 3
Minneapolis, MN

Greenbrier Wetland Services
Report 14-03

Mickey E. Heitmeyer
Brian J. Newman

May 2014

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Prepared For:

U. S. Fish and Wildlife Service
Region 3
Refuges and Wildlife
Minneapolis, MN

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Publication No. 14-03

Suggested citation:

Heitmeyer, M. E., and B. M. Newman. 2014. Hydrogeomorphic evaluation of ecosystem restoration and management options for Clarence Cannon and Great River National Wildlife Refuges. Prepared for U. S. Fish and Wildlife Service, Region 3, Refuges and Wildlife, Minneapolis, MN. Greenbrier Wetland Services Report 14-03, Blue Heron Conservation Design and Printing LLC, Bloomfield, MO.

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EXECUTIVE SUMMARY

This report provides a hydrogeomorphic (HGM) evaluation of ecosystem restoration and management options for the Clarence Canon (hereafter Cannon) and Great River National Wildlife Refuges (NWRs) along Pools 20-25 of the Upper Mississippi River System in northeast Missouri and west central Illinois. Cannon NWR contains 3,750 acres adjacent to Pool 25 while Great River NWR contains three divisions – Fox Island a 2,109 acre area adjacent to Pool 20; Long Island a 6,300 acres island-chute complex owned by the U.S. Army Corps of Engineers (USACE) and managed by the U.S. Fish and Wildlife Service along Pool 21; and Delair that contains 1,737 acres mostly within the Sny Agricultural Levee District along Pool 24. A Comprehensive Conservation Plan (CCP) was prepared for these refuge areas in 2004, which at the time were administered by the Mark Twain NWR complex. Recent management of these refuge areas has sought to implement CCP goals, but has also recognized the need for more holistic system-based approaches to future restoration and management efforts. A Habitat Management Plan (HMP) that identified future direct management activities for the refuges was completed in 2012.

This HGM report provides information to help identify options for future restoration and management and assist with implementation of refuge unit HMPs with the following objectives:

1. Describe the pre-European settlement (hereafter Presettlement) ecosystem condition and ecological processes in the Mississippi River region where refuge lands are located.
2. Document changes in the Mississippi River ecosystem from the Presettlement period with specific reference to alterations in hydrology, vegetation community

structure and distribution, and resource availability to key fish and wildlife species.

3. Identify restoration and management options and ecological attributes needed to restore specific habitats and conditions within various locations on Cannon and Great River NWRs.

Information was obtained on historical and contemporary geology and geomorphology, soils, topography, climate and hydrology, and plant animal communities of the Cannon-Great River NWR region. The surficial geomorphology of the refuge areas is a product of sediment and water discharge primarily during the last continental glacial-interglacial period. Fox and Long Islands are recent island-channel belt surfaces while Delair and Cannon set on relatively recent (Delair) and older (Cannon) alluvial surfaces deposited in the Holocene period. The far west side of Cannon includes a small area of elevated alluvial-colluvial fan material eroded from adjacent upland bluffs.

Soils on all refuge areas were formed by floodplain alluvial processes and contain various silt, loam, clay, and sand materials. Most soils are poorly drained to very poorly drained. Soils at Cannon are dominated by Carlow silty clay and Chequest silty clay loam. Soils at Delair are more complex than for other areas and represent heterogeneous topography and channel dynamics of the ancient Mississippi and Sny rivers. Dominant soils include Beaucoup, Ceresco, Darwin, Titus and Petrolia types. Long Island is mostly homogeneous Blake-Slacwater silt loam of relatively recent island formation. Fox Island contains adjacent linear bands of Fatima, Colo, Zook and Beaucoup soils arranged along relict river and side channels. The far northwest corner of Fox Island contains Perks loamy sand and represents part of a former sand terrace.

The climate of the Cannon-Great River NWR region is continental with relatively cold winters and long, hot summers. Total annual precipitation is about 35-40 inches, but is highly variable among years. Long-term precipitation records indicate alternating “wet” vs. “dry” years. Climate change models suggest that floods and droughts are likely to become more common and intense as regional and seasonal precipitation patterns change.

Discharge in the Mississippi River and its major tributaries in the Cannon-Great River NWR region are highly seasonal and reflect precipitation and runoff within their watersheds. River dynamics influence surface flooding and groundwater levels on all refuge areas and are the primary factor governing hydroperiods of floodplain wetlands on the refuges. Historic pre-river alteration (based on 1910 to 1929 period of record data) at Hannibal, Missouri indicates a regular 12-14 year periodicity of high and low river flows. This pattern changed after lock-and-dam construction on the Mississippi River, which now influences flow dynamics and river depth/flood patterns. Nearly 75% of historic floods in the Great River NWR region occurred from March to July. Typically, a drought year occurs about once every 10 years and data suggest a long-term trend of increasing river discharge and a slight increase in typical peak discharge.

A large groundwater aquifer, annually recharged by the Mississippi River, is present under Cannon and Great River NWRs. The aquifer is held in sand and gravel sediments and the groundwater surface is high and directly related to stage level in the Mississippi River. Consequently, in many locations the extent of groundwater interaction between the river and refuge floodplain wetlands is substantial; deeper sloughs and depressions often fluctuate with river levels, at least during high flow periods, as water "seeps" to the floodplain surface.

The heterogeneity of geomorphic surfaces, soils, and topography in the Cannon-Great River NWR region created diverse and highly interspersed vegetation communities distributed across elevation and hydrological gradients. Major natural communities/habitat types that historically were present included: 1) the main channel and islands of the Mississippi River and its major tributaries; 2) river "chutes" and "side channels"; 3) bottomland "oxbow" and depressional lakes; 4) early succession riverfront forest; 5) diverse floodplain forest; 6) oak-dominated bottomland hardwood forest; 7) upland-edge slope forest; 8) bottomland prairie, and 9) oak-savanna. A small area of unique sand prairie also apparently historically occurred on the west side of Fox Island. Relationships between community types and geomorphology, soils, topography, and flood frequency were used to prepare a HGM matrix that identified the potential distribution, composition, and area of Presettlement habitats for all refuge areas.

The historical and more contemporary changes to the Cannon-Great River NWR ecosystem are chronicled in the report including discussion of early settlement and land use changes, contemporary hydrologic and vegetation community changes, and refuge development and management. The primary ecosystem changes in the Cannon-Great River NWR region that need to be addressed for future restoration and management goals are: 1) reduced or eliminated river-floodplain connectivity; 2) loss of native plant communities, especially bottomland prairie and floodplain and bottomland hardwood forest types; 3) habitat fragmentation; 4) loss of floodplain topographic features and slough, chute, and side channel habitats; 5) altered water regimes and hydrology; and 6) spread of invasive and exotic species.

Based on information obtained and evaluated in this HGM study, specific recommendations are provided for each refuge area and summarized below:

Fox Island

- Restore sand prairie/savanna on the far west part of the area behind the mainstem levee on Perks soils.
- Plant and restore oak and pecan on the highest floodplain elevations that contain Colo soils. These sites have the highest probability of survival of the less water tolerant oak and pecan species because they will be flooded for the shortest periods during high river stage events.
- Restore diverse floodplain forest species composition on higher elevations that contain Beaucoup, Fatima, and Huntsville soils.
- Maintain riverfront forest on areas adjacent to rivers and sloughs/chutes with Gifford, Klum, and Wakeland soils.

- Encourage S/S habitats along sloughs and wetland depressions where Zook soils are present.
- Maintain connectivity of all chutes, sloughs, and side channels with higher stages of the Mississippi River. This may require removal of debris or excessive sediment obstructions and removal or modification of levees, berms, ditches, roads, and water-control structures that block or impeded interconnected flows during high river stages.
- Manage new HREP water-control structures to emulate natural patterns of spring and early summer flooding, summer drawdown, and then low levels in fall and winter in wetlands and sloughs. Further, evaluate all HREP structures to determine how and if they allow high stages of the Mississippi and Fox rivers to back water into, or create side channel flows, through the area.

Long Island

- Maintain forest on floodplain lands on the Division and do not develop new water-control or moist-soil impoundment infrastructure.
- Cooperate with the USACE to maintain and restore a more diverse floodplain forest community on higher elevations where flood frequencies are > 2 to 5-year return intervals. A systematic inventory of forest species related to elevations and flood frequencies on the Division is needed to determine where less water tolerant trees such as oak, elm, ash, pecan, and sugarberry can survive and be managed for.
- Management prescriptions currently identified in the most recent USACE Forest Management Plan for the division should be conducted. Specific desired actions include stratified tree plantings that place trees in locations that match their water tolerance (see above recommendation), careful timber stand improvement work, and invasive species control.
- Maintain the bathymetry of side channels, sloughs, and chutes so that higher stages of Mississippi River flows

can enter, flow through, and exit these areas and also provide widely distributed flood pulsing into floodplain areas. Maintenance of these channel/chute areas may require removal of some sediment or debris obstructions and or any older infrastructure. Sites of special interest include the LaGrange, Smoot, O'Dell, and Canton chutes.

Delair

- Evaluate the potential to restore small areas of bottomland prairie on Petrolia, Coffeen, and Ceresco soil locations.
- Restore floodplain forest on Titus and Wakeland soil locations.
- Restore BLH on Darwin and Beaucoup soils, except in seepage areas, which are better suited for wet prairie and moist-soil habitats
- Maintain riverfront forest on Ambraw, Zumbro, and Sarpy sandy soils.
- Manage the Swan Lake complex as a connected PEM/seasonal herbaceous floodplain lake-marsh site. Modify existing water-control infrastructure to allow Swan Lake to be connected with the slough area in Cattail Marsh and create a more natural PEM/seasonal herbaceous wetland complex.
- Manage other wetland areas as independent units that can replicate natural seasonal and long-term patterns of flooding and drying. This management will require improvements in existing water-control infrastructure to create more independent water management among the wetlands. For example, the Cattail Marsh complex is subject to seepage from high stages of the Mississippi River and will naturally have a longer and more dynamic flooding regime than for example the Hanei marshes. Consequently, Cattail Marsh will tend to have more semipermanent flooding and persistent emergent type wetland communities compared to shorter duration moist-soil habitats in other areas.

- Manage moist-soil units to create diverse seasonal herbaceous communities using water management and physical disturbances including fire, tillage, rolling, mowing, and rotational agricultural cropping.
- Control invasive and undesirable vegetation such as reed canary grass using a combination of chemical and physical manipulation.

Cannon

- Restore a prairie-savanna community on the high elevations with Dupo and Moniteau soils.
- Restore diverse floodplain forest communities on Blackoar and Klum soil areas.
- Maintain riverfront forest adjacent to the Mississippi River on Dockery soils.
- Reconfigure the existing wetland units to: 1) enlarge units; 2) restore natural topographic features such as historic meander scrolls, ridges, and swales; and 3) enable water management to maintain more natural mosaics of seasonal herbaceous and bottomland prairie habitats. Some reconfiguration will require changes to existing water-control and supply infrastructure such as outlined in the 2013 HREP proposal. Where possible wetter regimes that encourage a more natural wet prairie/marsh community should be developed on Carlow soils and drier regime moist-soil habitats should attempt to align with Chequest and Twomile soils.
- Manage slough and natural wetland depression areas for semipermanent wetland habitats. Specifically, attempt to restore the Big Pond area to its larger, undivided, configuration and manage it for seasonally and interannual dynamic natural water regimes.
- Manage vegetation in restored prairie and herbaceous wetland units to sustain productive assemblages of species using dynamic water management, tillage, mowing and rolling, periodic fire, and rotational agricultural cropping.

- Increase river-floodplain connectivity by constructing the levee setback and exterior berm degrade features proposed in the HREP.

Future management of the Cannon-Great River NWR lands should include regular monitoring and directed studies to determine how ecosystem structure and function are changing, regardless of whether restoration and management options identified in this report are undertaken. Management activities on Aransas NWR should be done in an adaptive management framework where: 1) predictions about community response and water issues are made relative to specific management actions and 2) follow-up monitoring is conducted to evaluate ecosystem responses to the action. Especially important categories of information and monitoring needs for refuge areas include:

- Ground and surface water quantity and quality
- Restoring natural water flow patterns and water regimes
- Long-term changes in vegetation and animal communities


Karen Kyle

INTRODUCTION

The Clarence Cannon (hereafter Cannon) and Great River National Wildlife Refuges (NWR) contain about 15,000 acres of floodplain habitats along Pools 20-25 of the Upper Mississippi River System (UMRS) from just south of Keokuk, Iowa to Annada, Missouri (Fig. 1).Cannon NWR contains 3,750 acres adjacent to Pool 25 of the Mississippi River and was established in 1964 using funds from federal "duck stamp" sales. Cannon formerly was part of a private agricultural levee district and all but a few hundred acres of the refuge are protected by large levees. Historically, Cannon has been managed primarily to provide waterfowl foods using intensively developed moist-soil wetland units, agricultural lands, and small areas of greentree reservoir. An 800-foot spillway was constructed in the Mississippi River levee on the southeast side of Cannon in 1996 and it allowed high stage floodwaters to enter the refuge at levels 4.2 feet below the crest of the mainstem Mississippi River levee. Since 2004, the spillway was raised to 3.1 foot below the river crest. Great River NWR contains three units or divisions - Fox Island, Long Island, and Delair (combined 10,146 acres) (Fig. 1). The northernmost division, Fox Island, contains 2,109 fee-title acres adjacent to Pool 20. Formerly known as the Gregory Landing Division, the original 1,037 acres in the refuge were purchased in 1989 with additional acres purchased in 1996 and 1997. Flooding events on the Mississippi River greatly affect Fox Island and historically little active water or habitat management occurred on the division. A U.S. Army Corps of Engineers (USACE) Habitat Rehabilitation and Enhancement Project (HREP) was initiated on Fox Island in 2009 to restore 215 acres of bot-

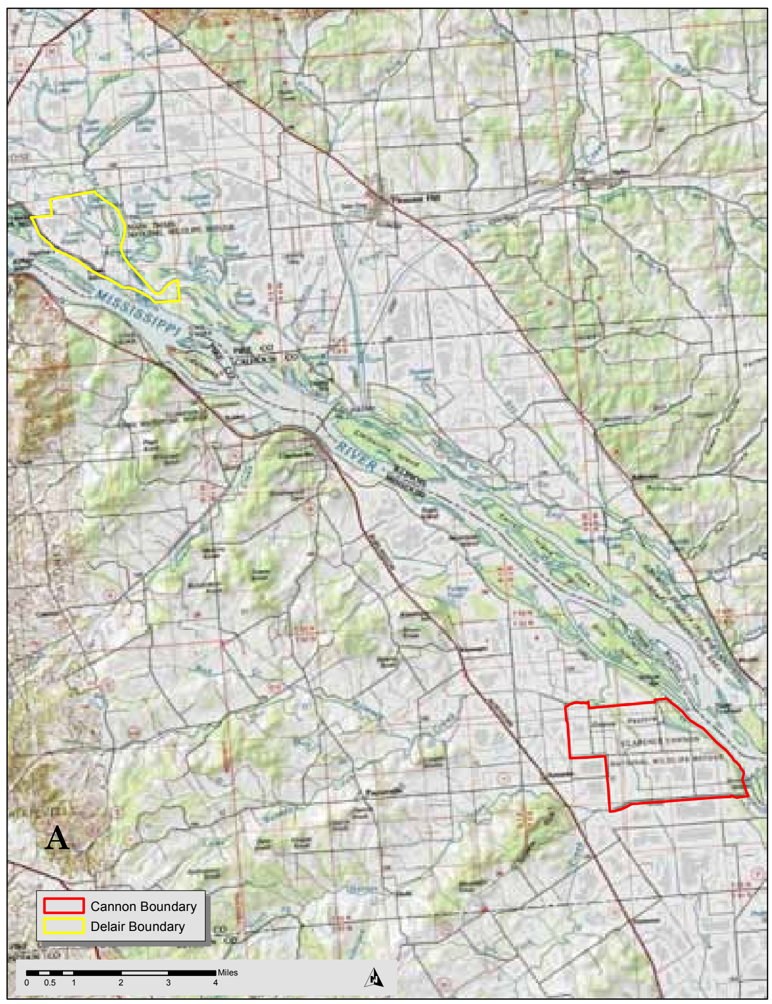

Figure 1. General location of a) Clarence Cannon and Delair and b) Long and Fox Island NWRs.

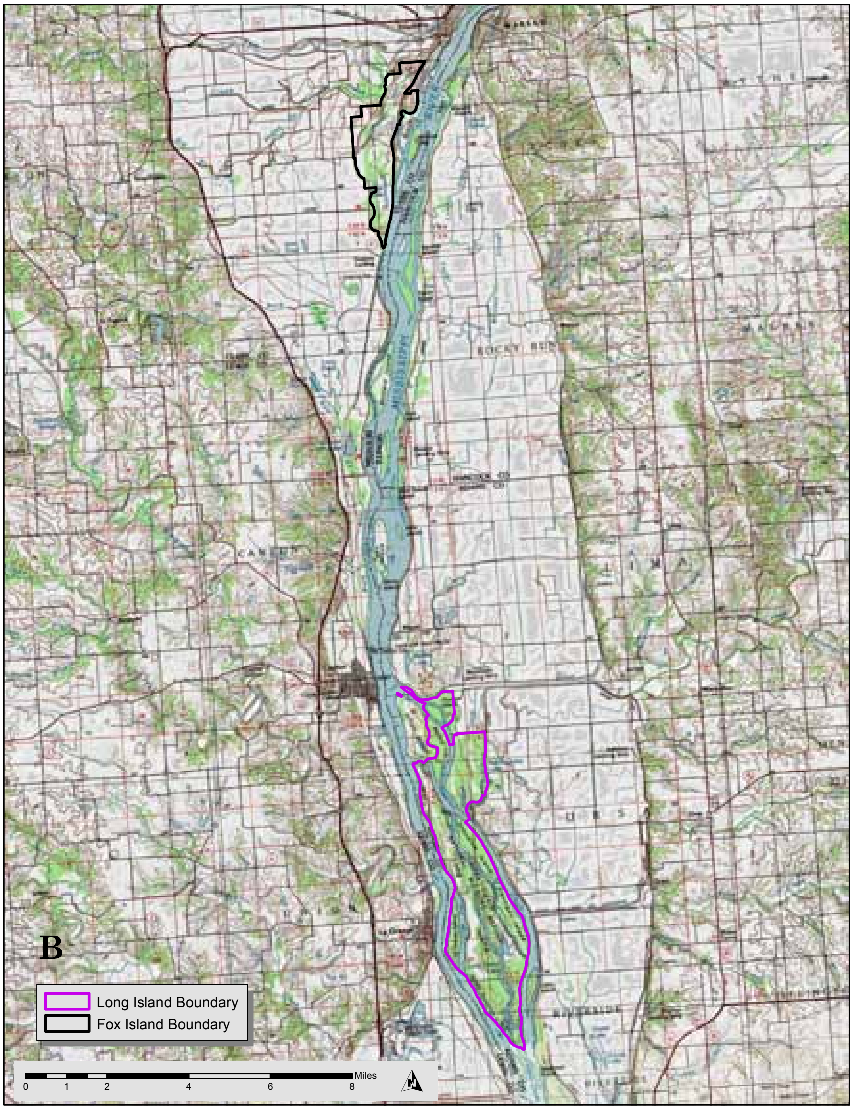

Figure 1, continued. General location of: a) Clarence Cannon and Delair and b) Long and Fox Island NWRs.

tomland hardwood forest, enhance water-control management on 78 acres of wetland, and plant 98 acres to native grasses and forbs (USACE 2008). Long Island contains about 6,300 acres of non-leveed island-floodplain complex in the main Mississippi River channel area in Pool 21 about 6 miles north of Quincy, IL. Long Island is owned by the USACE and the U.S. Fish and Wildlife Service (USFWS) manage it under General Plan (GP) agreement (USFWS 2004). Most of the Long Island Division is riverfront forest interspersed with island/floodplain sloughs, side channels, chutes, and oxbow lakes. Little active management occurs on Long Island. The Delair Division contains 1,737 acres along Pool 24 in Pike County, IL. The division was acquired in 1965 and 1976 and is within the Sny Agricultural Levee District except for one small island. Originally mostly cropland, the division now has considerable water-management infrastructure to manipulate water levels in moist-soil units, managed lakes, and cropland along with remnant stands of floodplain forest.

A Comprehensive Conservation Plan (CCP) was prepared for Cannon and Great River NWRs in 2004, which at the time were under administration of the Mark Twain NWR (USFWS 2004). Initially, Cannon and the Great River divisions were part of the Annada District of the Mark Twain NWR, but in 2000, Mark Twain NWR was split into five separate NWRs and the Fox Island, Long Island, and Delair divisions became Great River NWR, managed from the Cannon NWR headquarters. Recent management of the refuge has sought to implement CCP goals, but also recognized constraints inherent with each refuge unit, such as water-control capabilities, and the need for more holistic system-based approaches to future restoration and management efforts. A Habitat Management Plan (HMP) that identified future direct management activities for the refuges was completed in 2012 (USFWS 2012).

This report provides a hydrogeomorphic (HGM) evaluation of the Cannon-Great River NWR region to help identify options for future ecosystem restoration and management and assist with implementation of refuge unit HMPs. The HGM evaluation provides data and information about historical communities and their ecological processes, along with general recommendations for ecosystem restoration and management in the region, as it specifically relates to future management of the NWRs. Recently, HGM has been used to evaluate ecosystem restoration and management options on many NWR's throughout the U.S. (e.g., Heitmeyer et al. 2013a, Heitmeyer and Aloia 2013). These HGM evaluations obtain and analyze historical and current information about: 1) geology and geomorphology, 2) soils, 3) topography and elevation, 4) hydrology, 5) aerial photographs and maps, 6) land cover and plant/animal communities, and 7) physical anthropogenic features of ecosystems (Heitmeyer 2007a, Klimas et al. 2009, Theiling et al. 2012, Heitmeyer et al. 2013b). The HGM information provides a context to understand the physical and biological formation, features, and ecological processes of lands within a NWR and the surrounding region. This historical assessment provides a foundation, or baseline condition, to determine what changes have occurred in the abiotic and biotic attributes of the ecosystem and how these changes have affected ecosystem structure and function. Ultimately, this information helps define the capability of the area to provide key ecosystem functions and values and identifies options that can help to restore and sustain fundamental ecological processes and resources.

Objectives for this HGM evaluation of Cannon and Great River NWRs are:

1. Describe the pre-European settlement (hereafter Presettlement) ecosystem condition and ecological processes in the Mississippi River region where refuge lands are located.
2. Document changes in the Mississippi River ecosystem from the Presettlement period with specific reference to alterations in hydrology, vegetation community structure and distribution, and resource availability to key fish and wildlife species.
3. Identify restoration and management options incorporating ecological attributes needed to restore specific habitats and conditions within various locations on Cannon and Great River NWRs.

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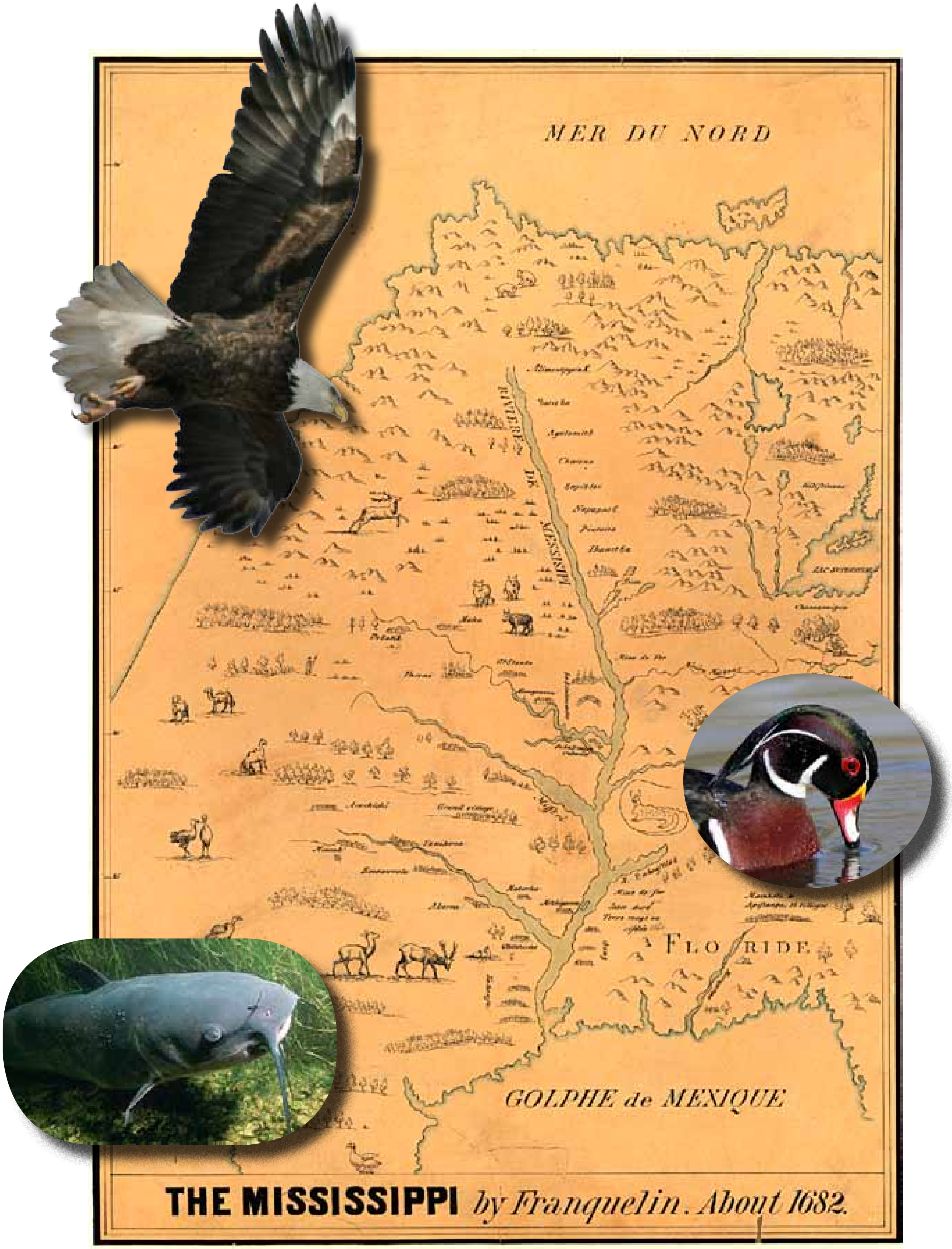

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THE HISTORICAL
CANNON-GREAT RIVER NWR ECOSYSTEM

GEOLOGY AND GEOMORPHOLOGY

The surficial geomorphology of the Mississippi River and its floodplain at Cannon and Great River NWRs is a product of sediment and water discharge primarily during the last continental glacial-interglacial cycle. The history of the Upper Mississippi River geology and sequential changes in the course and morphology of the river channel and floodplain is provided in Heitmeyer and Bartletti (2012). Cannon and Great River NWRs are within the Des Moines River, Quincy, and Sny Anabranch ecoregions, defined by relatively distinct hydrogeomorphic attributes (Fig. 2, Heitmeyer 2009).

The Des Moines River ecoregion lies immediately downstream of the narrow, highly incised Keokuk Gorge and is dominated by a large sediment fan formed where the Des Moines River joins the Mississippi River. The Mississippi River channel crosses the Holocene floodplain several times in this reach and lateral channel adjustments have been active in this area. Large areas of remnant natural levees and crevasse splays are present on the paleo-floodplain surfaces and become interfingered with colluvial slope material in eastern areas. The active river floodplain is coincident with tributaries on the Iowa and Missouri sides of the floodplain. Only a few large islands are present in the reach. The ecoregion includes Navigation Pools 20 and 21.

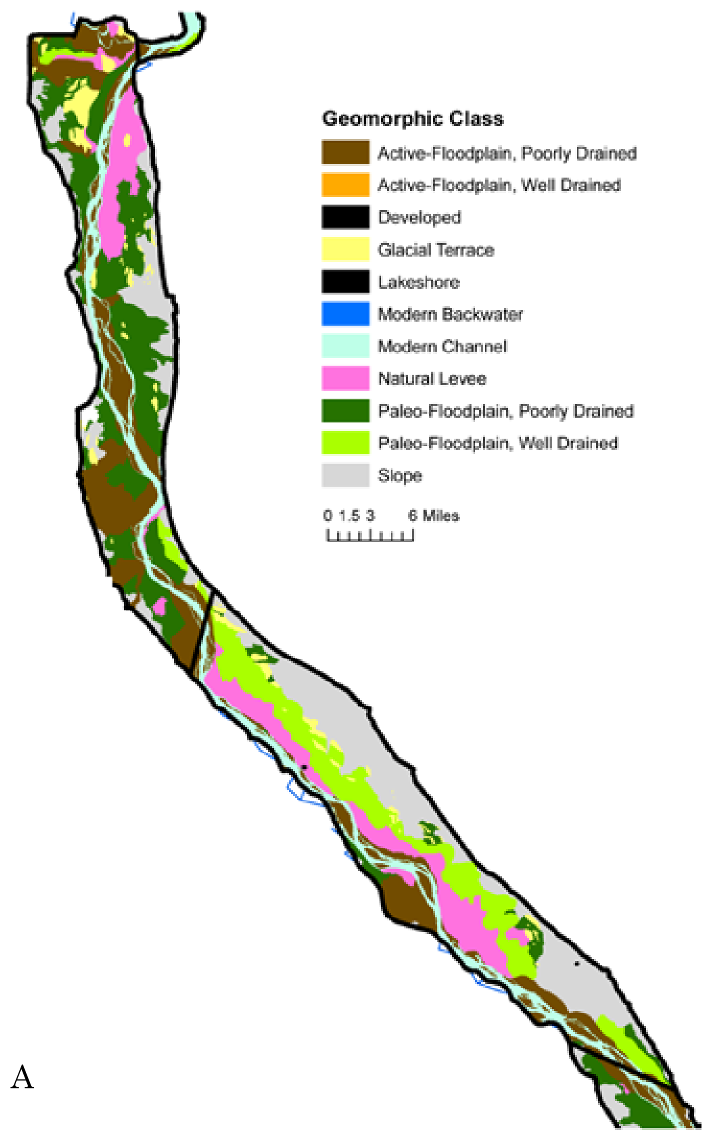


Figure 2. Location of the: a) Des Moines and Quincy and b) Sny Anabranch and Columbia Bottoms ecoregions and surface geological features (from Theiling 2010).

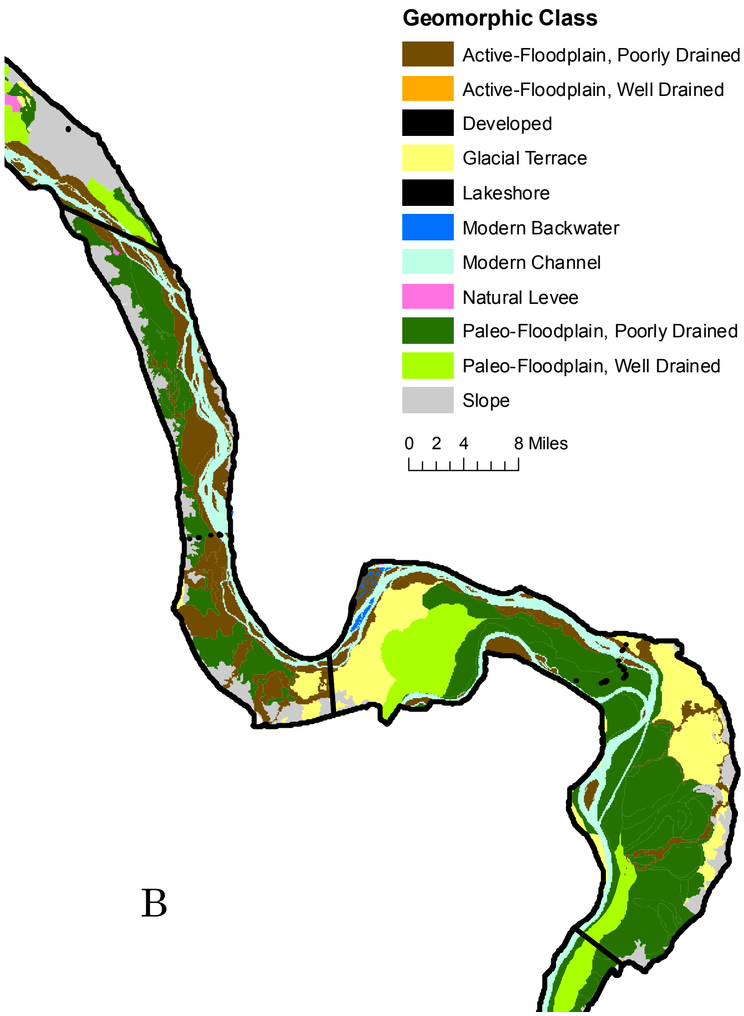


Figure 2, continued. Location of the: a) Des Moines and Quincy and b) Sny Anabranch and Columbia Bottoms ecoregions and surface geological features (from Theiling 2010).

The Quincy Anabranch Reach portion of the Mississippi River and its floodplain runs close to high limestone bluffs along the Missouri side of the river and includes a complex sequence of older and recent Mississippi River natural levees, the old Yazoo meander belt, remnant parts of the Savanna and Kingston Terrace, and alluvial fans and colluvial slopes on the Illinois side of the floodplain (Mason and Knox 1997). The floodplain on the Missouri side of the Mississippi River is narrow and includes mostly late Holocene channel belts and islands. The South Fabius River joins the Mississippi River just south of Hannibal, Missouri, but the position of the Mississippi River immediately next to the floodplain bluffs in this area precluded the development of a large tributary fan/delta at this juncture. Active floodplain area in Missouri increases downstream and near the Salt River confluence area, which contains a large tributary fan at the Ted Shanks CA (Heitmeyer 2008b). At this point the river moves off the Missouri bluff for about 10 miles before returning to a position along the Missouri bluff line. This area includes Navigation Pool 22 and part of Navigation Pool 24.

The Sny River enters the Mississippi River just north of Moser, IL and at this point the Mississippi River makes a marked shift to flow along the Illinois bluff line (Petterchak 2002). The river slope flattens in this reach and develops a wide, low, and relatively flat floodplain in Missouri south to the confluence of the Missouri and Mississippi Rivers. This Missouri-side floodplain has a high amount of active and paleo-floodplain surficial area, tributary fans, and low amounts and distribution of older alluvial terraces and natural levees. On the narrow Illinois-side floodplain, colluvial slopes interfinger with floodplain alluvium. Islands in this reach typically are less than 200 acres. This reach includes parts of Navigation Pools 24, 25, and 26.

Current geomorphic mapping of Great River NWR lands indicate that Fox and Long Islands are recent island-channel belt surfaces while Delair and Cannon set on relatively recent (Delair) and older (Cannon) alluvial deposition surfaces deposited in the Holocene period (Fig. 3). The far west side of Cannon includes a small area of elevated alluvial-colluvial fan material eroded from adjacent upland river bluffs.

SOILS

Contemporary USDA soil maps describe major soil types on Cannon and Great River NWRs (Fig. 4). Soils on all refuge lands were formed by floodplain alluvial processes and contain various silt, loam, clay, and sand materials. Most soils are poorly drained to very poorly drained (Fig. 4). Many of the listed soil types are "competing" series, which means they are similar with slight variations in floodplain location, inundation, and sand content.

Generally, soils at Cannon are dominated by Carlow silty clay and Chequest silty clay loam that formed under wet prairie vegetation communities. The east side of Cannon contains Dockery and Blackoar silt loams, which reflect recent scouring and deposition of material by the Mississippi River, and these sites contained riverfront forest communities. Areas of Twomile and Moniteau silt loam are present in slightly higher floodplain areas, while interior areas of Cannon that are mapped as "water" by the soil maps reflect relict floodplain depressions, sloughs, and river meander swales. Soils at Delair are more complex than for other divisions and represent heterogeneous topography and channel dynamics of the ancient Mississippi and Sny rivers. Dominant soils include Beaucoup silty clay loam, Ceresco loam, Darwin silty clay, Titus silty clay loam, and Petrolia silt loam – each formed under different historical water regime and vegetation community situations. Generally, Beaucoup soils reflect historic presence of floodplain forest or marsh grass vegetation. Titus soils occupy shallow depressions and backswamp surfaces. Sparta and Sarpy sand-based soils occur on higher well-drained areas. Areas mapped as water reflect the location of the relict Swan Lake wetland complex. Long Island is mostly homogeneous Blake-Slacwater silt loam soils of relatively recent island formation. A small area of Raveenwash silt loam is present in the north part of the area, and apparently is an older natural levee deposition. A small area contains "Riverwash," which is a sand and gravel mix. Water areas on soil maps indicate side channel and river-connected slough channels. Fox Island contains adjacent linear bands of Fatima, Colo, Zook, and Beaucoup soils arranged along relict river and side channels. Most of these soil areas supported floodplain or riverfront forest communities. The far northwest corner of Fox Island contains Perks loamy sand, an area where sand was deposited along a former Mississippi River channel.

TOPOGRAPHY

The topography on Great River NWR divisions is heterogeneous and reflects the

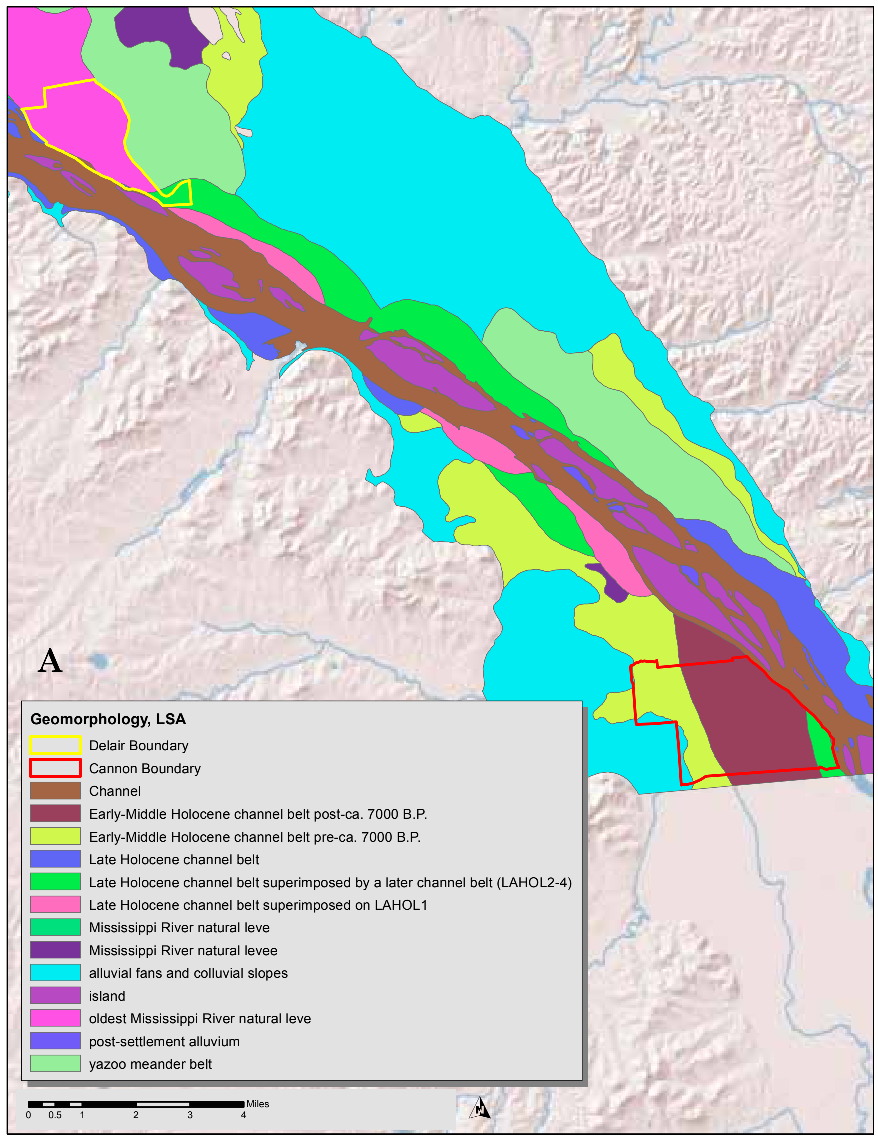


Figure 3. Land sediment assemblages (surficial geomorphology) maps for: a) Clarence Cannon and Delair and b) Long and Fox Island NWRs (from Hajic 1990, 2000 and Bettis et al. 1996, 2008).

extensive fluvial dynamics of the ancient and recent Mississippi River floodplain (Fig. 5). Recently completed digital elevation models for Cannon identify the many depression features on the floodplain including the Big Pond, Crane Pond, Rabbit Ears and GTR7 management unit areas (Fig. 6). At Delair, the Upper and Lower Swan Lake complex along with relict channel pathways of the Sny River are evident in the Hanei, Shoveler, and Lower Butcher marsh sites. At Long and Fox Islands, the many side channels and chutes of the Mississippi River are pronounced and readily visible on Light Detection and Ranging (LiDAR) topographic maps.

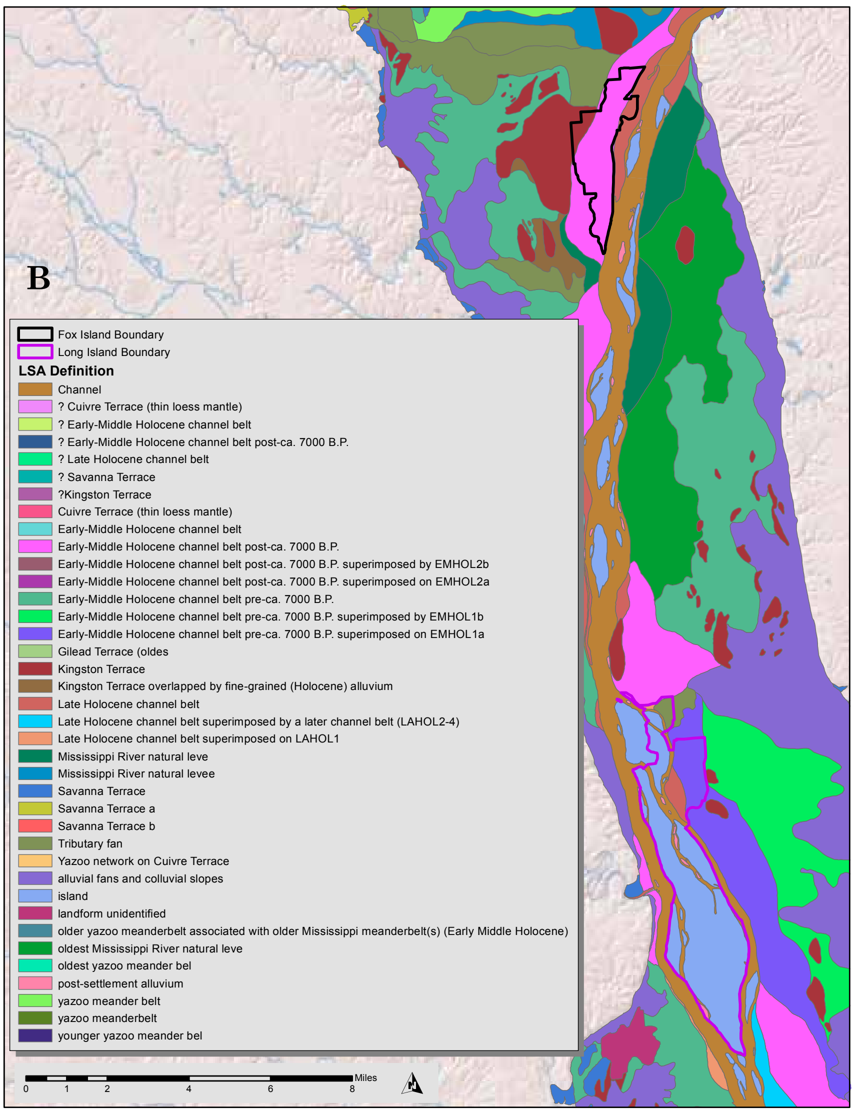


Figure 3. Land sediment assemblages (surficial geomorphology) maps for: a) Clarence Cannon and Delair and b) Long and Fox Island NWRs (from Hajic 1990, 2000 and Bettis et al. 1996, 2008).

CLIMATE AND HYDROLOGY

The climate of the Cannon-Great River NWR region is continental with relatively cold winters and long, hot summers. Slight climate variation occurs from north (Fox Island) to south (Cannon) among the refuge divisions, but generally strong seasonal patterns of temperature and precipitation occur throughout the region (representative Elsberry, MO data are shown in Tables 1-3). The growing season averages about 200 days/year starting the last week of April and ending the first week of October on average. Winter temperatures cold enough to freeze shallow wetlands solid are common. Total annual precipitation is about 35-40 inches, but is highly variable among years ranging from 20 to over 50 inches (Table 2, Fig. 7). Highest rainfall typically occurs in May and precipitation averages 3-4 inches per month from March through October. Long-term precipitation records indicate alternating "wet" vs. "dry" years. During the period of record, 1950-57, 1960-61, 1971-72, and 2012 were particularly dry. Years with wetter than normal precipitation included 1970, 1980-85, 1993, 2009, 2011, and 2013.

No obvious trends in increasing or decreasing precipitation over time are evident for weather stations in the region (Steffenville, Bowling Green, and Elsberry, MO – see Newman 2012). Climate change model scenarios suggest that floods and droughts are likely to become more common and more intense as regional and seasonal precipitation patterns change. Heavy precipitation events have increased in the region over time and rainfall is more concentrated into heavy events, with longer hotter periods in between (Kunkel et al. 2003). Some evidence suggests an increase in mean temperature values during since the 1950s (Newman 2012). One

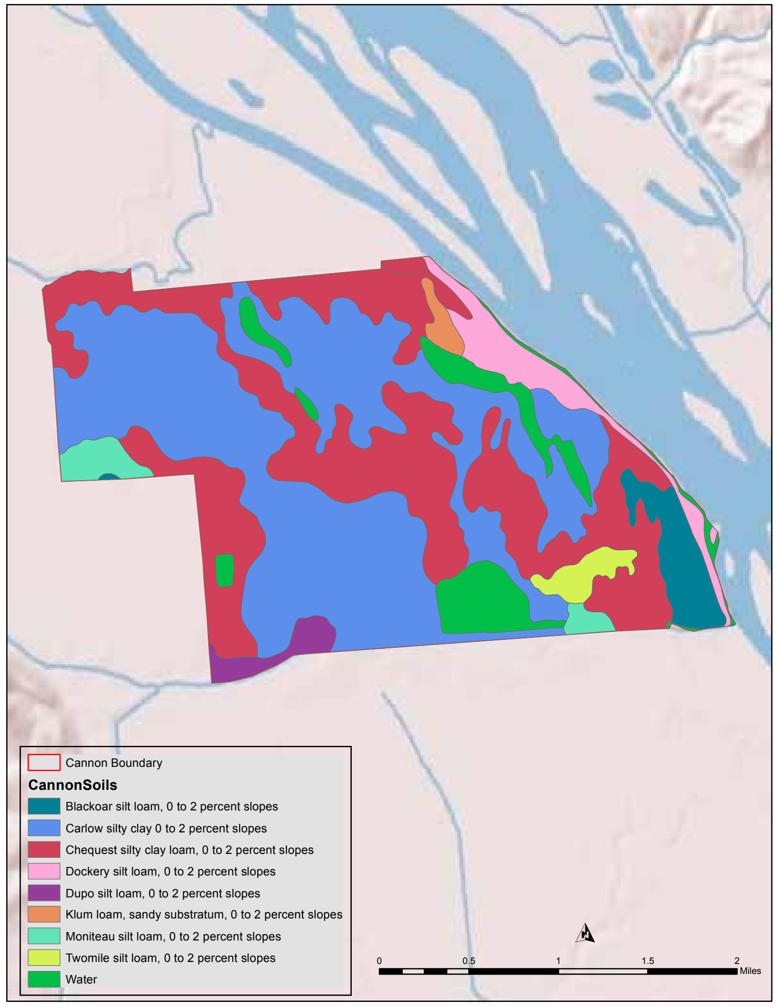


Figure 4. Soils on: a) Clarence Cannon, b) Delair, c) Long Island, and d) Fox Island NWRs (USDA SSURGO data).

climate projection scenario suggests a 13-15 degree F increase may happen by the end of this century (UCS 2009). Another scenario suggests an increase of only 1.6 degrees F by 2100 (Magness et al. 2011). A comparison of Pacific Decadal Oscillation (PDO) index of the Oct-Mar precipitation (% of average) and Oct-Mar mean temperature at Bowling Green, MO, suggests that during "cool phase" years (negative index on Fig. 8), the region will be warmer and drier than is typical for the region, a result similar to that found by Nigam et al. (1999). The PDO is often described as a long-lived El Nino pattern of Pacific climate variability (Zhang et al. 1997). The PDO often has a longer periodicity (15-20 years) and was negative throughout 2012 (Newman 2012).

Discharge in the Mississippi River and its major tributaries in the Cannon-Great River NWR region are highly seasonal and reflect local precipitation and runoff within their watersheds, especially the larger UMRS. River dynamics influences surface flooding and groundwater levels at all refuge divisions and is the primary factor governing hydroperiods of floodplain wetlands on the refuges. Mississippi River flows and overbank/backwater flooding in the UMRS results from snowmelt, rainfall, and various combinations of snowmelt and rainfall. Intra-annual seasonal variation of Mississippi River flows and flooding follows a strong one-year cycle of about six months of higher flows in spring and summer and six months of lower flows in fall and winter. Historic pre-river alteration (based on 1910 to 1929 period of record data) at Hannibal, MO (approximate mid-point of north-south latitude for the refuge divisions) indicate a regular 12-14 year periodicity of high and low river flows (Fig. 8). This gauge data indicate consistent 5-year duration higher flows followed by 5-year lower flows prior to 1930. This pattern changed somewhat after lock-and-dam construction on the Mississippi River, which now influences flow dynamics and river depth, and now low-flow periods are compressed to about two years duration on average with intervening years of higher flows of about five years in length (Franklin et al. 2003). The El Nino/Southern Oscillation climate patterns in North America are linked to the long term patterns of regional precipitation and Mississippi River flows. Nearly 75% of historic floods in the Great River NWR region occurred from March to July; March and June had more floods than other months. Generally, the magnitudes of annual floods are correlated with winter snow depth in the Upper Mississippi River Valley and also with early summer rainfall in the local river watersheds.

Analyses of the North River at Palmyra, MO (a larger tributary to the Mississippi River in the Cannon-Great River NWR region) indicates that mean discharge and drier conditions were present in the 1950s, 1960s, and early 2000s, while the 1980s and the last 5 years (2008-2013) were

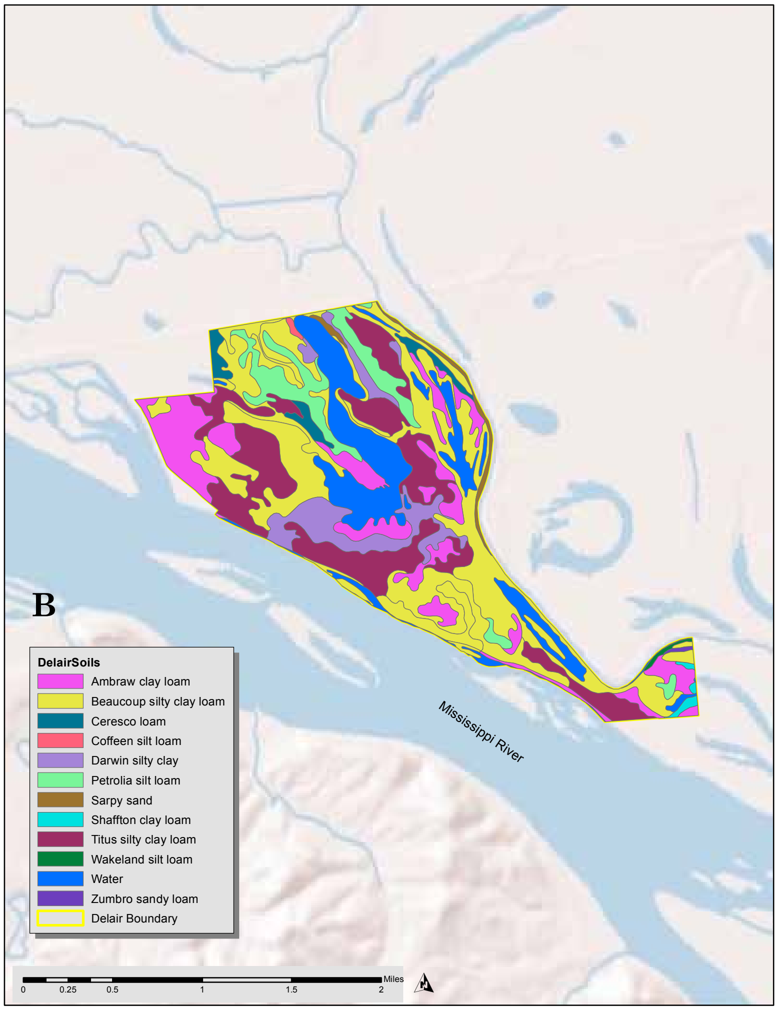


Figure 4. Soils on: a) Clarence Cannon, b) Delair, c) Long Island, and d) Fox Island NWRs (USDA SSURGO data).

wetter than normal (Fig. 9). Typically, a drought year occurs about once every 10 years and the data suggest a long-term trend of increasing discharge and a slight increase in typical peak discharge. Analyses of the Fox River at Wayland, MO showed a strong season peak of discharge in spring, but no apparent long-term trends in peak discharge (Fig. 10, Hrabik 1992). Generally overbank flooding from the Mississippi and Fox rivers at the Fox Island Division has a return interval of about every two years, indicating that overbank flooding of the Division occurs about 50% of the years, primarily as backwater flooding in spring caused by higher stages on the Mississippi River.

A large groundwater aquifer, annually recharged by the Mississippi River, is present under the Cannon and Great River NWRs. This aquifer is held in sand and gravel sediments and the potentiometric groundwater surface is high and directly related to stage level in the Mississippi River. Consequently, in many locations the extent of groundwater interaction between the Mississippi River and refuge floodplain wetlands is substantial; deeper sloughs and depressions often fluctuate with river levels, at least during high flow periods, as water "seeps" to the floodplain surface. Groundwater monitoring wells at Hannibal, MO (an indication of groundwater levels immediately adjacent to the Mississippi River) and at Wayland, MO (an indication of groundwater levels near the Fox River) indicates strong seasonal patterns coincident with river levels (Fig. 11). The Mississippi River and the saturated vadose zone (i.e., the shallow zone extending from the ground surface to the water table) surrounding it, is likely acting as a hydraulic dam to groundwater flow causing water to rise to the surface as seeps and springs in some areas (Newman 2012). This is especially true on the Delair Division, where high Mississippi River stages cause substantial seepage into the Cattail Marsh area. The eastern half of Cannon NWR is within the Silurian-Devonian aquifer, which is carbonate based rock, and contains generally porous rock with high levels of transmissivity. The western half of Cannon and the Great River NWR divisions are not classified into a primary aquifer, as the alluvial surfaces in these areas extends to depths that existing wells cannot measure. The water elevation for the northern part of Cannon is about 425 feet MSL, or about 15 feet below ground surface on average, but with obvious seasonal variation such as seen at Hannibal, MO (Fig. 11, Newman 2012).

PLANT AND ANIMAL COMMUNITIES

The Presettlement UMRS landscape north of St. Louis occupied a central continental position that lies between the great grassland biome to the west, conifer forests to the north, and deciduous forests to the east and south (Nigh and Schroeder

2002). Post-glacial climate fluctuations caused the invasion and retreat of many different plant and animal associations and caused a rich biological diversity in the region. HGM matrices of the historic distribution of major vegetation communities/habitat types in the Middle Mississippi River Corridor (Heitmeyer 2008b), the Ted Shanks CA in Pool 24 (Heitmeyer 2008), Rip Rap Landing in Pool 25 (USACE 2009), and Two Rivers NWR in Pool 26 (Heitmeyer and Westphall 2007) demonstrate the relationships of community to geomorphic surface, soils, and flood frequency in the Cannon-Great River NWR region.

The heterogeneity of geomorphic surfaces, soils, and topography in the Cannon-Great River region created diverse and highly interspersed vegetation communities distributed across elevation and hydrological gradients (Fig. 12). Major natural communities/habitat types that historically were present in the region included: 1) the main channel and islands of the Mississippi River and its major tributaries, 2) river "chutes" and "side channels", 3) bottomland lakes, 4) riverfront forest, 5) floodplain forest, 6) oak-dominated bottomland hardwood forest (BLH), 7) slope forest, 8) bottomland prairie, and 9) oak-savanna. Lists of fauna and flora along with scientific names of species in these habitats is provided in Zawacki and Hausfater 1969, Terpening et al. 1974, Korschgen and Toney 1976, Galatowitsch and McAdams 1994, Nigh and Schroeder 2002, Nelson 2005, and Heitmeyer and Westphall 2007). A cross-walk of community classification schemes is provided in Table 4.

The main channels of the Mississippi River and its major tributaries (e.g., Des Moines, Fox, Salt, Sny) contained open water with little or no plant communities other than phytoplankton and algae (Theiling 1996). During times of low river levels in late summer and early fall, some river chutes and side channels became disconnected from main channel flows and held stagnant water that supported sparse herbaceous "moist-soil" plants that germinated on exposed mud flats. During high river flows chutes and side channels were connected with the main channel and scouring action of river flows prevented establishment of rooted plants in these habitats. The extent and duration of river connectivity was the primary ecological process that controlled nutrient inputs and exports, primary and secondary productivity, and animal use of chutes and side channels. A wide variety of fish were present in the Mississippi River and tributary rivers and their side channels (e.g., Pflieger 1975), and these habitats also were used by many amphibians, a few aquatic mammals, and some water and shorebirds (Smith 1996).

A few large permanent "islands" historically occurred within the Mississippi River or tributary channels in the Cannon-Great River region (e.g., the complex of islands adjacent to the Ted Shanks CA in northeast Missouri) and

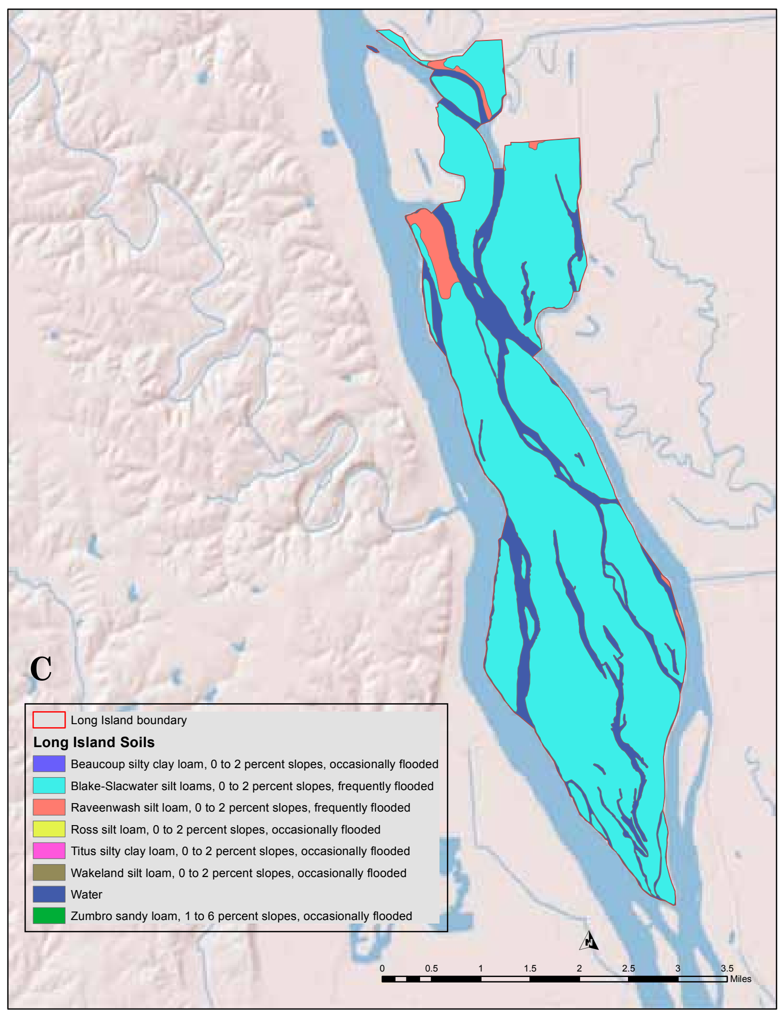


Figure 4. Soils on: a) Clarence Cannon, b) Delair, c) Long Island, and d) Fox Island NWRs (USDA SSURGO data).

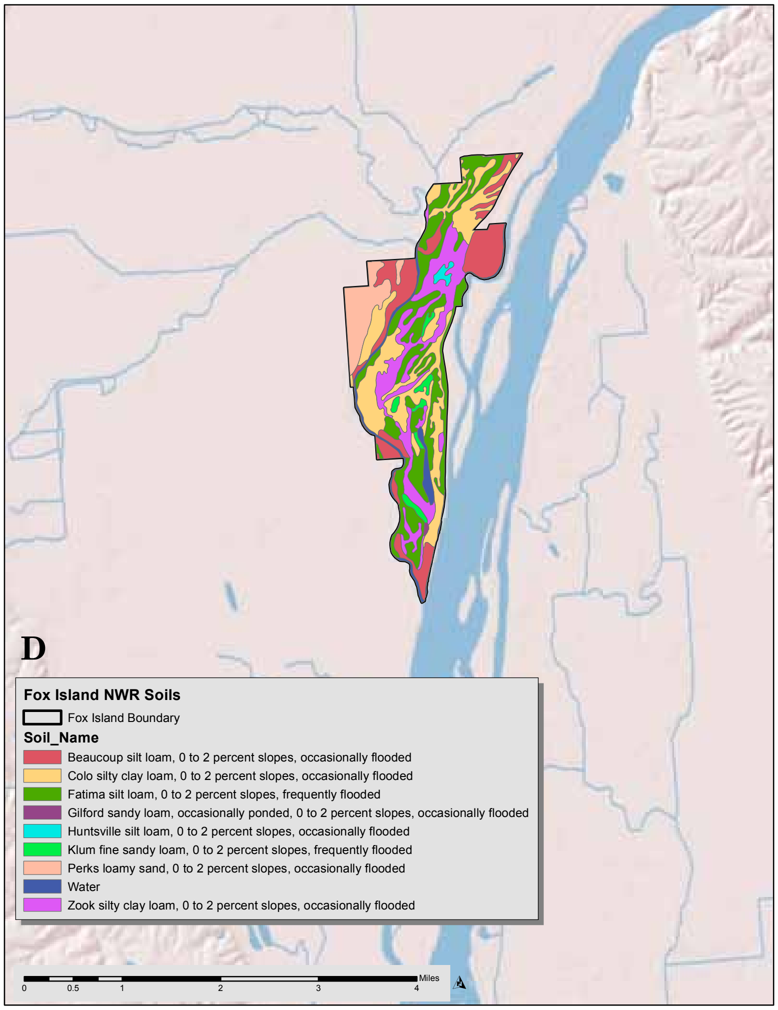


Figure 4. Soils on: a) Clarence Cannon, b) Delair, c) Long Island, and d) Fox Island NWRs (USDA SSURGO data).

“bars” were common on the edges of channels, especially on the downward side of major bends (Mississippi River Commission 1881, Collins and Knox 2003, Brauer et al. 2005). Most “islands” in the Cannon-Great River region usually were separated from the floodplain by narrow, often highly sediment-filled, older side channels. During dry periods these “islands” became extensions of terrestrial floodplain surfaces. Vegetation on islands and bars depended on size, configuration, and connectivity to banks (Turner 1936). The degree and duration of flooding and connectivity to either the river or floodplain controlled ecological attributes and animal use of islands and river bars. Most islands and bars historically were 1-4 feet below adjoining floodplain elevations and were overtopped during annual high flow periods. During floods, river bars often were extensively scoured or destroyed, and new bars were created in other locations. Vegetation on bars was mostly pioneering plants that germinated on newly deposited alluvium. Annual herbaceous plants and seedlings of cottonwood, sycamore, and willow were the most common plants. Larger islands in the Cannon-Great River region such as Ziegler, Gilbert, Denmark, Blackbird, North and South Fritz, Mozier, Clarksville, and Slim contained riverfront forest communities with some aquatic and moist-soil plants in interior swales and sloughs. The Westport Island Natural Areas in Lincoln County, Missouri are remnant examples of riverfront forest and off-channel slough areas (Missouri Natural Areas Committee 1996).

Bottomland lake-type wetlands historically were present in some locations along major tributary floodplains and occupied abandoned channels of the Fox, Salt, Sny, and Cuivre river corridors (Bareis 1964, Munson 1974, Woerner et al. 2003). The location, age, and size of bottomland lakes determined depth, slopes, and consequently composition and distribution of vegetation communities. The edges of these lakes typically dry for short periods during summer and contain persistent emergent (PEM) and seasonal herbaceous vegetation (often termed “moist-soil” vegetation, see e.g., Fredrickson and Taylor 1982). PEM includes arrowhead, cattail, rushes, river bulrush, sedges, and spikerush. Seasonal herbaceous vegetation usually is dominated by smartweeds, millet, panic grasses, sprangletop, sedges, spikerush, beggarticks, and many other perennial and annual “moist-soil” species. The distribution of PEM and herbaceous communities in bottomland lakes depends on length and frequency of summer drying seasonally and among years (sees previous hydrology section about long-term dynamics of flood events and intervening dry periods). In drier periods, herbaceous communities expand to cover wide bands along the edges of bottomland lakes, while in wetter periods herbaceous plants are confined to narrow bands along the edges of deeper open water (see also discussion in Heitmeyer and

Westphall 2007). Historically, the Upper and Lower Swan Lake complex on Delair was surrounded by shrub/scrub (S/S) and forest habitats (e.g., Heitmeyer 2008a). S/S communities represented the transition area from more herbaceous and emergent vegetation in the aquatic part of bottomland lakes to higher floodplain surfaces that supported trees. S/S habitats typically were flooded a few inches to 2-3 feet deep for extended periods of each year except in extremely dry periods. S/S habitats typically were dominated by buttonbush and willow. Often a natural levee was present along the edges of bottomland Lakes and these areas supported floodplain forest species assemblages. The edges of bottomland lakes in the Salt, Sny, and Cuivre river corridors contained mixed hardwood floodplain forest species (Heitmeyer and Bartletti 2012, USACE 2009)

Bottomland lakes support a high diversity of animal species. Historically, fish moved into these lakes for foraging and spawning when they became connected with the Mississippi, Fox, Salt, and Sny rivers during flood events. Many fish subsequently move back into the main channel when flood water receded or after they spawned or fattened during flood events; some fish remain to populate the deeper lakes (e.g., Sparks 1995). Bottomland lakes also support high density and diversity of amphibian and reptile species and some species, such as turtles, move into and out of these lakes similar to fish (e.g., Tucker 2003). Aquatic mammals regularly use bottomland lakes and more terrestrial mammals travel in and out of these areas for seasonal foraging, breeding, and escape cover during dry periods. Bird diversity in these lakes is high, and extremely high densities

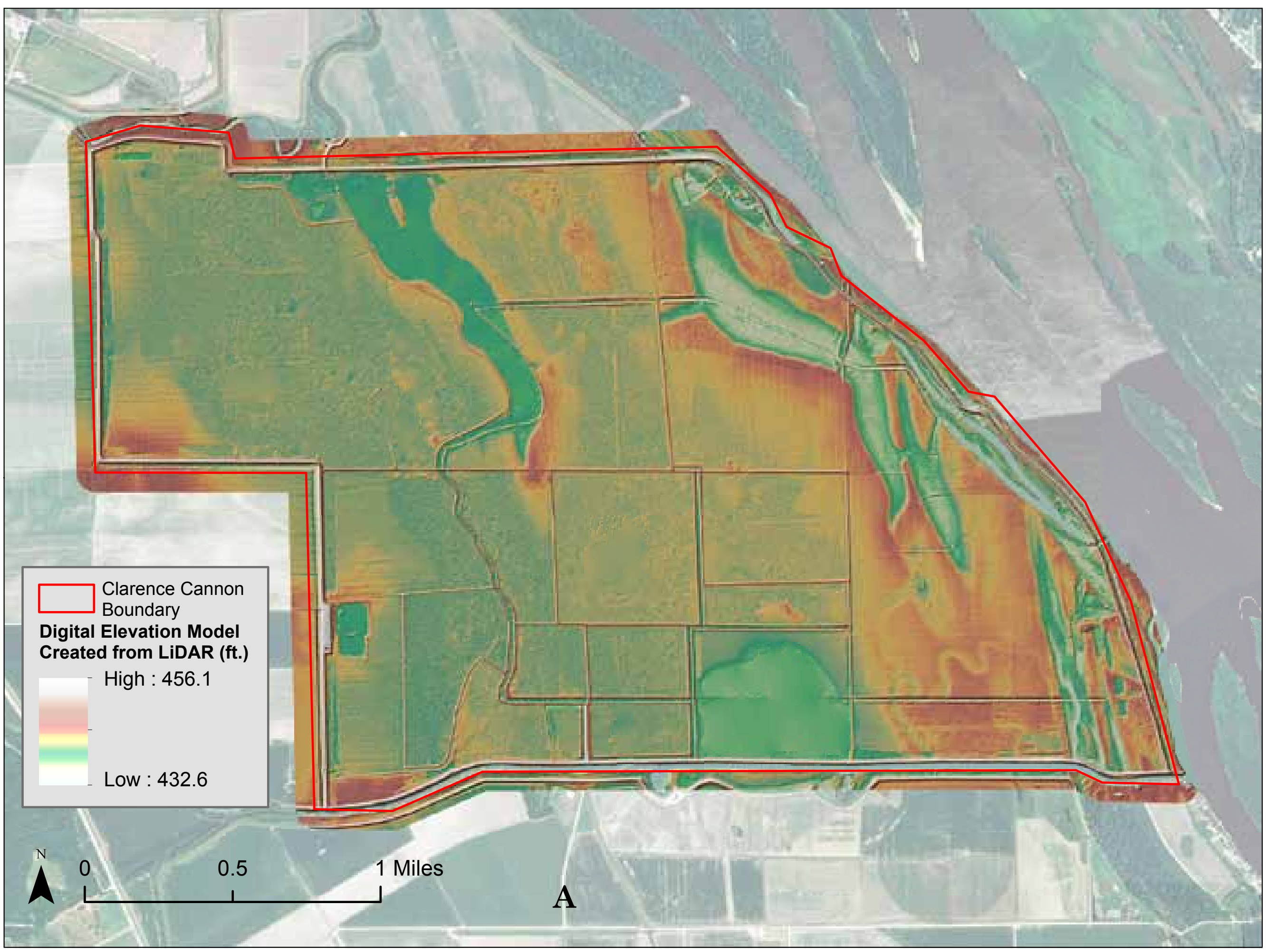


Figure 5. Digital elevation maps (DEM) created from LiDAR surveys for: a) Clarence Cannon NWR; b) Delair; c) Long Island; and d) Fox Island units of Great River NWR (data from USFWS).

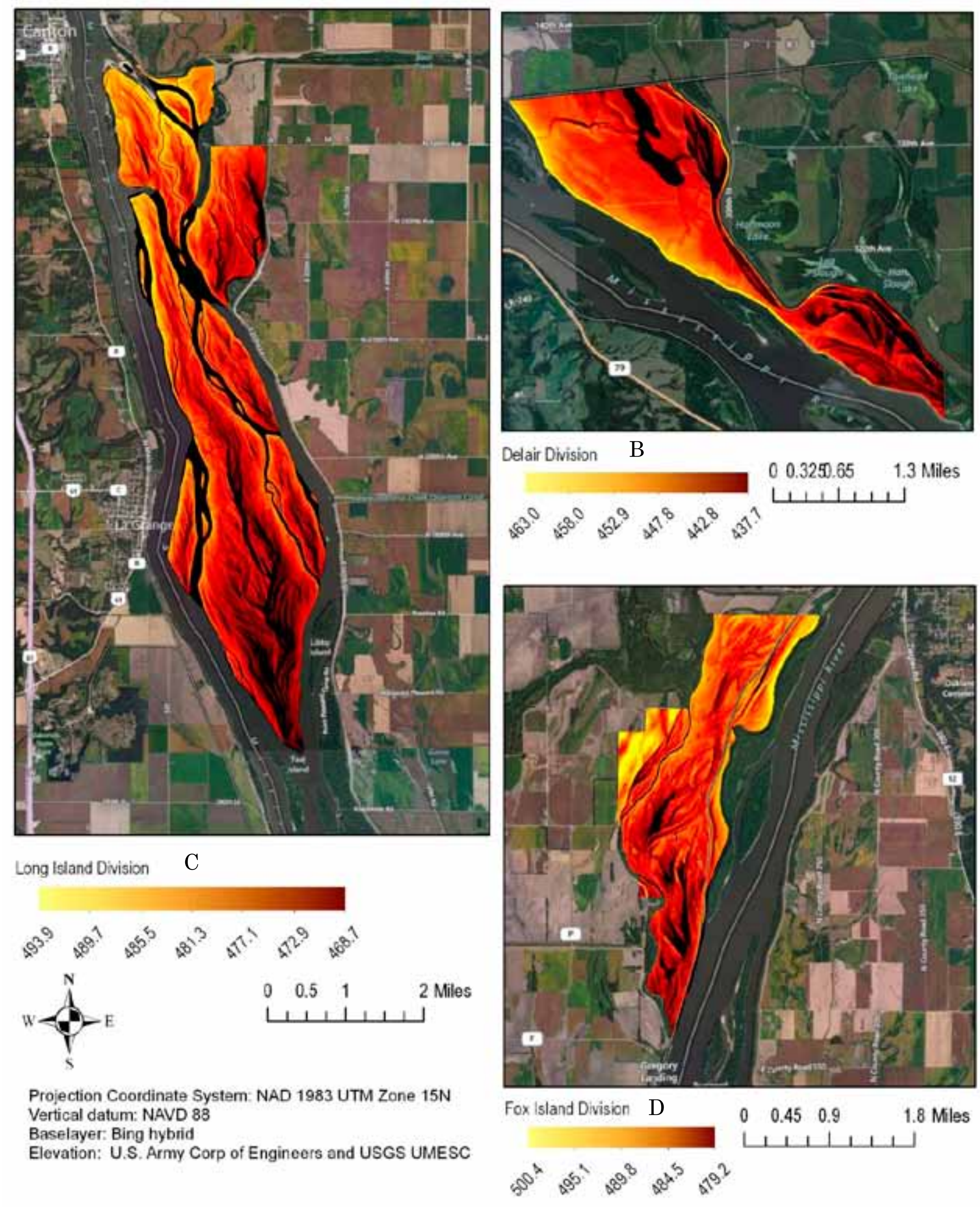


Figure 5, continued. Digital elevation maps (DEM) created from LiDAR surveys for: a) Clarence Cannon NWR; b) Delair; c) Long Island; and d) Fox Island units of Great River NWR (data from USFWS).

of waterfowl, rail, shorebirds, and wading birds use these habitats for foraging, nesting, and resting sites (Heitmeyer 2008a).

Riverfront forest (also called "river-edge forest" in some older botanical literature) was present on island and bar surfaces, some point bar areas near the current channel of the Mississippi River and its tributaries and along the edges of some abandoned channels (Hus 1908, Chmurny 1973, Gregg 1975, Mohlenbrock 1975, Patterson

1989, Nelson 1997). These geomorphic surfaces contained recently accreted lands and were sites where river flows actively scoured and deposited silt, sand, gravel, and some organic debris within the last decade or so. Soils under riverfront forest communities, especially on chute and bar surfaces, were young, annually overtopped by flood waters, highly drained, influenced by groundwater dynamics as the Mississippi River (and tributaries) rose and fell, and contained thin veneers of silt (Heitmeyer and Bartletti 2012). Riverfront forest habitat was dominated by early succession tree species and varied from water tolerant species such as willow and silver maple in low elevations and swales to intermediate water tolerant species such as American elm, green ash, cottonwood, sycamore, pecan, and hackberry on ridges. Pin oak and pecan occasionally are present in higher elevations in riverfront forest areas, but these species have high mortality during extended flood events and oak/pecan patches probably were small and scattered (see e.g., Green 1949, Yeager 1949). Shrubs and herbaceous vegetation in riverfront forests were sparse near the edge of rivers but dense tangles of vines, shrubs, and herbaceous vegetation were present on higher elevations away from the river where alluvial silts were deposited. The dynamic scouring and deposition in island and bar areas limited the tenure of many woody species except on the highest elevation ridges where species such as cottonwood and sycamore often became large mature stands (e.g., Turner 1936).

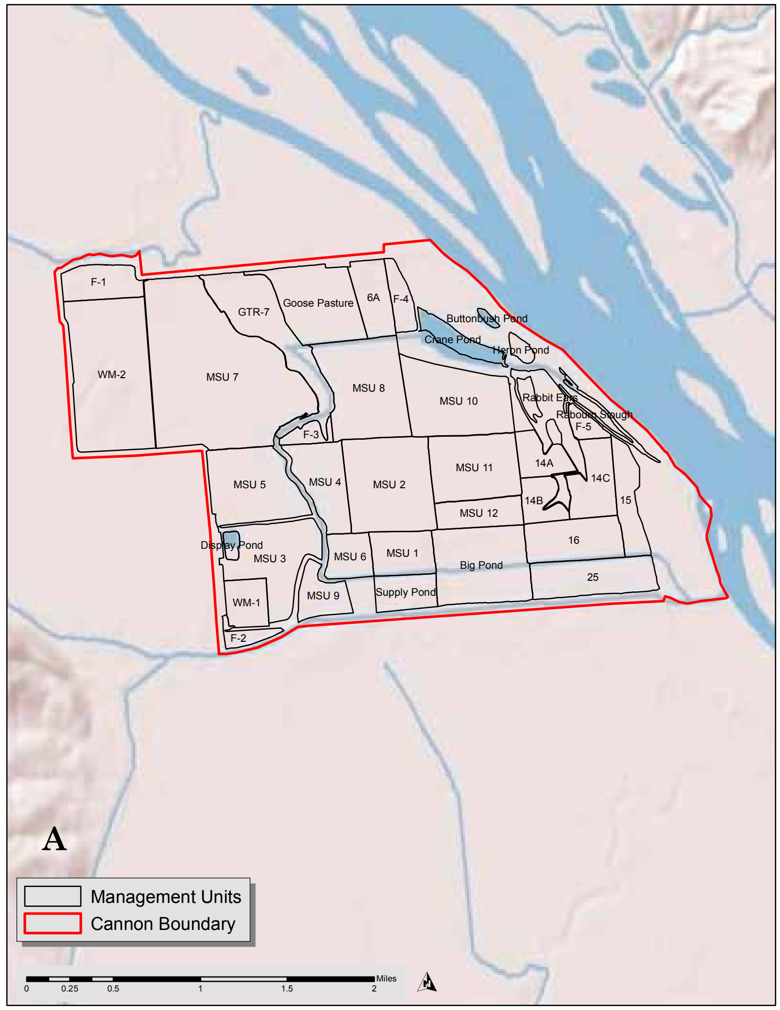


Figure 6. Management units on: a) Clarence Cannon NWR; b) Delair, c) Long Island, and d) Fox Island units of Great River NWR (from USFWS data).

Riverfront forests are used by many animal species, especially as seasonal travel corridors and foraging sites. Many bird species nest in riverfront forests, usually in higher elevation areas where larger, older, trees occurred (Papon 2002). Arthropods are abundant in riverfront forests during spring and summer and these habitats also contained large quantities of soft mast that is consumed by many bird and mammal species (e.g., Knutson et al. 1996). Few hard mast trees are present in riverfront forests, but occasional "clumps" of pecan or oak provide locally abundant nuts. The very highest elevations in chute and bar areas provide at least some temporal refuge to many ground-dwelling species during flood events (Heitmeyer et al. 2005). As mentioned previously, the many forested islands in the Mississippi River channel, along with chute and bar deposits contain good examples of the riverfront forest community type.

Floodplain forest communities historically covered some floodplain areas in the Cannon-Great River region on Holocene channel belt point bar surfaces and along tributary streams (Hus 1908, Telford 1927, Gregg 1975, Robertson et al. 1978, Yin 1998, 1999). This forest type represents a transition zone from early succession riverfront forest located on coarse-sediment island and bar

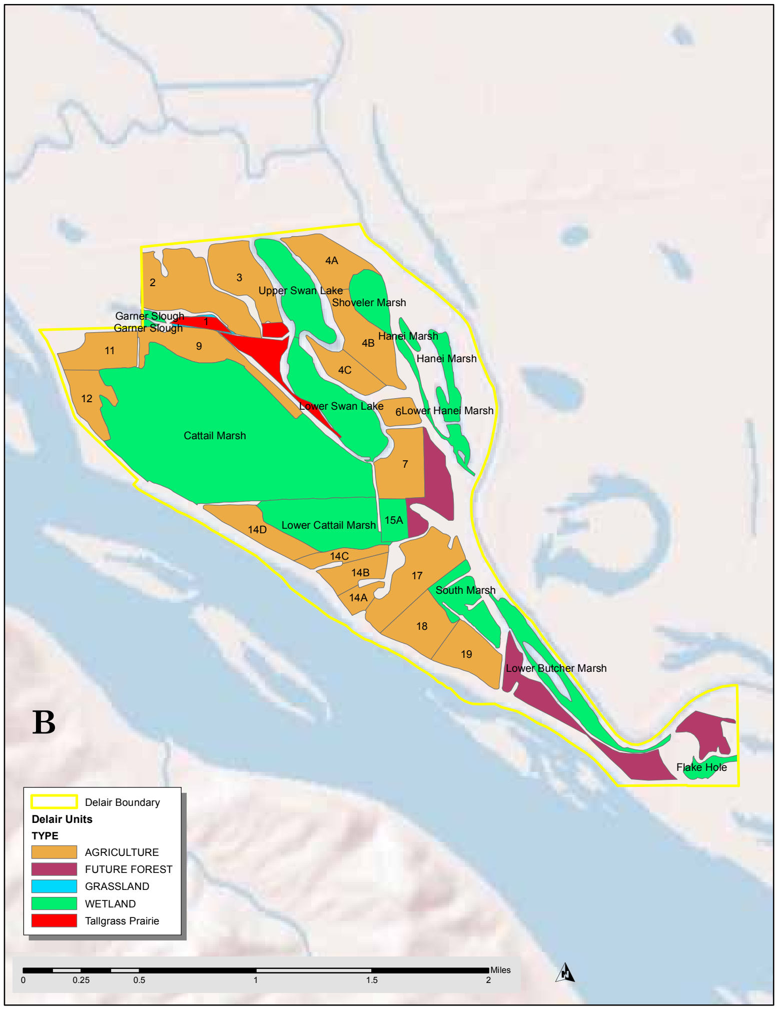


Figure 6, continued. Management units on: a) Clarence Cannon NWR; b) Delair, c) Long Island, and d) Fox Island units of Great River NWR (from USFWS data).

surfaces to oak and pecan-dominated BLH forests that occurred in clay-type soils on tributary fans and tributary corridors. Floodplain forest habitats typically developed on mixed silt loam soils where older point bar "ridge-and-swale" topography occurred. Most of these older point bar surfaces were within the 1-2 year flood frequency zone (Heitmeyer 2008b, Heitmeyer and Bartletti 2012). Floodplain forests were dominated by elm, ash, sweetgum, sugarberry, and box elder but included many other species depending on elevation and soil type. Some botanical literature calls this forest type the "sugarberry-elm-sweetgum" zone (e.g., Gregg 1975). Higher elevation ridges, and older remnant natural levees, often contained pecan, pin oak, bur oak, swamp chestnut oak, honey locust, and scattered hickory. Low elevation swales within floodplain forests contained a mix of more water tolerant species that included willow, cottonwood, maple, and sycamore on coarser soil sediments to oak, ash, sweetgum, and pecan in Holocene meander belt point bar swales that had thicker layers of silt and clay. Some authors have described floodplain forests communities as BLH (e.g., Yin et al. 1997), however, floodplain forests are ecologically distinct from typically defined BLH communities that are dominated by oaks (e.g., Conner and Sharitz 2005, Heitmeyer 2008a, b). Good remnant examples of floodplain forests in the QCA include the south end of the B.K. Leach CA in Lincoln County, Missouri and the Stump Lake, Calhoun Point, and south Rip Rap Landing CA's in Illinois.

Larger, deeper, swales within floodplain forests in the Cannon-Great River region historically contained surface water for extended periods of the year and supported gradients of vegetation similar to forest-edge bottomland lakes but at a smaller spatial scale. Dense understory layers of hophornbeam, spicebush, and paw-paw and many vines such as trumpet-vine, grape, poison ivy, Virginia creeper, peppervine, and catbrier are present in many floodplain forests. Early explorers often commented on the relatively "impenetrable" nature of these floodplain forests (e.g., Collot 1826). Herbaceous cover typically is extensive in higher elevations of floodplain forests and includes many herbs such as Virginia snakeroot, smooth ruellia, honewart, elephant's foot, fleabane, and rough bedstraw.

The floral and elevation diversity of floodplain forests provides abundant resources to many animal species. Many mammals, including rodents, ungulates, and canids historically used these habitats as did many amphibians and reptiles. Bird abundance in floodplain forests is high and includes species that breed, winter, and migrate through the area (Knutson et al. 1996, Papon 2002). During flood events, floodplain forests often become refuge for species that occur in lower elevations of riverfront forest habitats. During larger floods fish move into floodplain forests for spawning and foraging.

BLH, also sometimes called lowland-depressional forest (e.g., Leitner and Jackson 1981), contained greater amounts of hard mast producing oaks and pecans than Floodplain Forest communities and was present on older tributary fans and tributary channel corridors, and the old Yazoo meander belt along the Sny River (Green 1949, Yeager 1949, Nelson and Sparks 1998, Heitmeyer 2008a). BLH typically had thick clay-type soils and were seasonally flooded from local or upland runoff, slow backwater or “sheetflow” overbank flows of the Sny and backwaters of larger Mississippi River floods. Good remnant examples of BLH in the QCA include higher elevations on the Ted Shanks CA in Missouri and sites along the Sny River including forested areas on the Delair NWR and the north end of the Rip Rap Landing CA in Illinois.

BLH forests in the QCA typically are dominated by pin, bur, and swamp chestnut oak (Missouri Department of Conservation 1973, Korschgen and Toney 1976, Nelson and Sparks 1998, USACE 2009). Other common trees in this community include elm, ash, hackberry, and hickories. At Ted Shanks CA, where BLH has been extensively studied, it occurs in areas that typically flood for only a few weeks to up to two months in wetter winters and in spring. Soil saturation in BLH communities occasionally is extended for 3-4 months annually, at least during wetter years; however oak trees cannot tolerate extended growing season flooding. The highest elevations in BLH communities historically were flooded for only a few weeks each spring and some sites were dry for several years during dry periods. Lower depressions in BLH often include more water tolerant species such as green ash, silver and red maple, pecan, and buttonbush. Common privet, honeysuckle, greenbriar, and poison ivy are common understory plants and herbaceous cover in BLH often is extensive because of limited, mostly dormant season, flooding (Korschgen and Toney 1976).

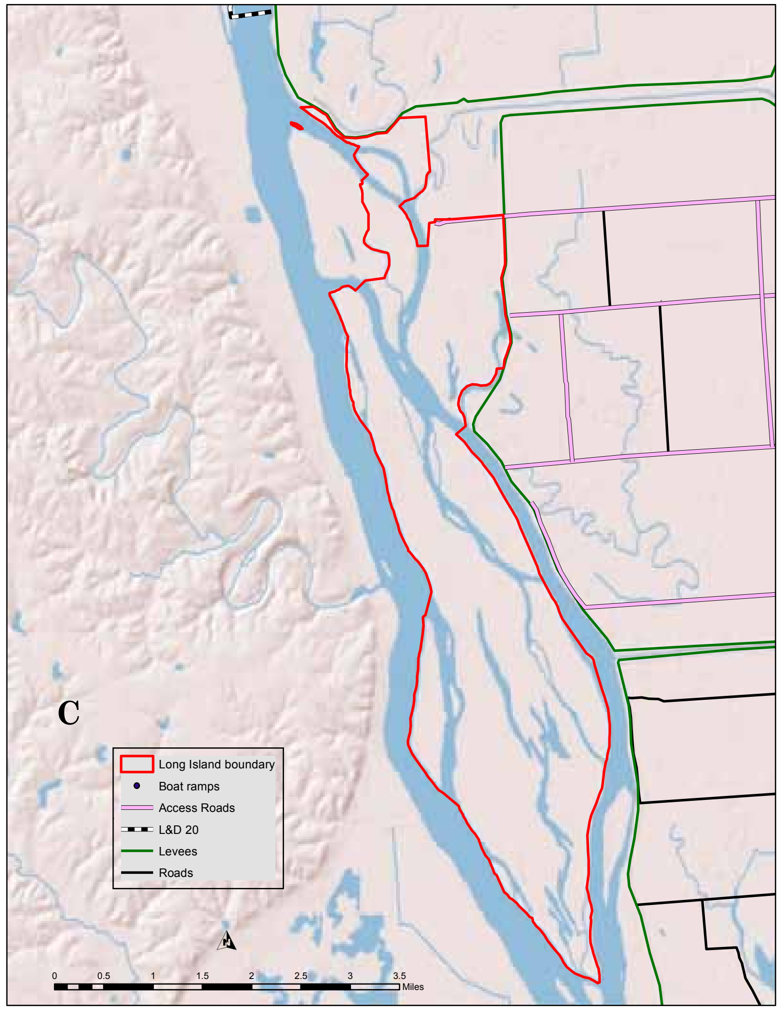


Figure 6, continued. Management units on: a) Clarence Cannon NWR; b) Delair, c) Long Island, and d) Fox Island units of Great River NWR (from USFWS data).

Animal diversity is high in BLH communities because of the deep alluvial soils, seasonal flooding regimes, diverse plant communities, high structural complexity, and rich detrital food bases (Heitmeyer et al. 2005). Foods within BLH become available in many seasonal “pulses” that provided many different types of nutrients used by many trophic levels and within many niches. Consequently, this community supports large numbers of species and individuals. The primary ecological process that sustain BLH communities and their productivity is seasonal, mostly dormant-season, flooding. Regular disturbance events also occur in this ecosystem through periodic extended flooding or drought, wind storms, and fire in at least the higher elevations.

Slope forests historically occupied alluvial fans and higher terraces along the edges of the Mis-

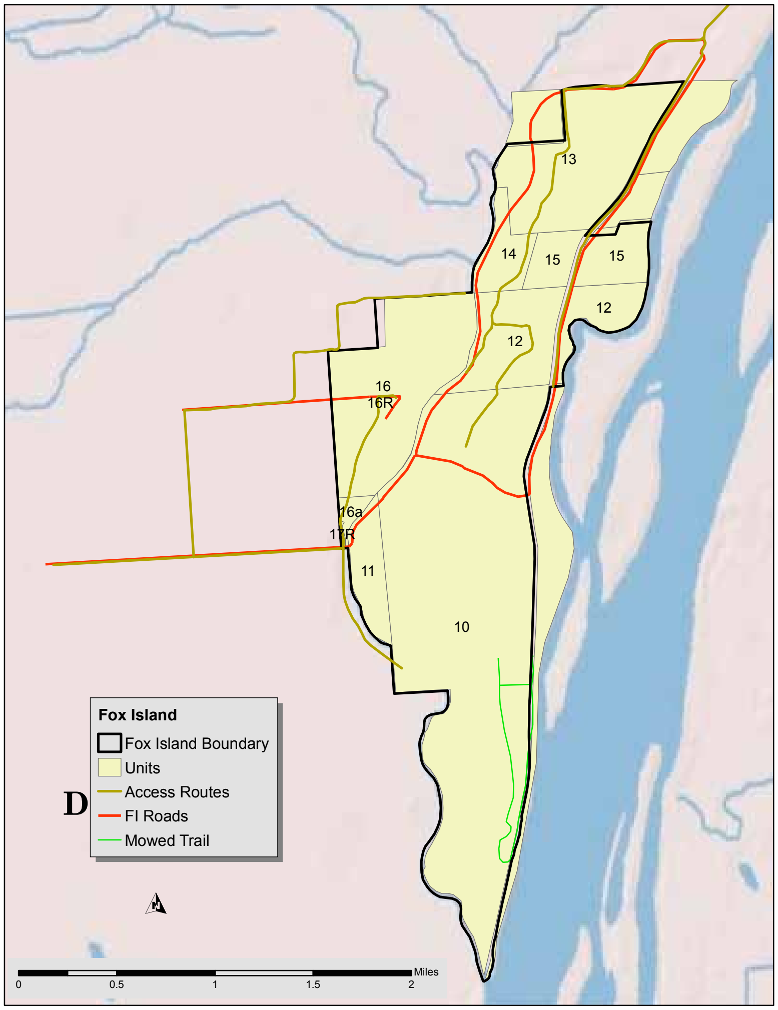


Figure 6, continued. Management units on: a) Clarence Cannon NWR; b) Delair, c) Long Island, and d) Fox Island units of Great River NWR (from USFWS data).

sissippi River floodplain (Munson 1974, Chmurny 1973, Gregg 1975). The far west side of Cannon NWR contains a small bottom-end area of an alluvial fan and likely supported Slope Forest or a mix of slope forest and bottomland prairie in a savanna-type community. This site sits on Dupo soils. Slope forests are not flooded except during extreme Mississippi River flood events. Even during extreme floods, only the low elevation bottom parts of slopes historically would have been inundated. Most water flowed off the slopes in a wide overland sheetflow manner and only minor drainages originated from the slopes. Slopes often were bounded by slightly larger drainages that originated in bluffs and uplands. Some slope areas in the American Bottoms were bounded by prairie. In these prairie-forest transition sites, savanna was present as narrow bands at the bottom of the slopes and probably was maintained by occasional fire. Fires in these areas may have originated in either the floodplain bottoms or uplands and likely contributed to sustaining the diverse mix of woody, herbaceous, and grass species.

Many animals used slope forests and these sites also were preferred sites for Native American settlements (e.g., Bauxer 1978). These sites contained rich floral communities, multiple food types, and relief from periodic flooding and bothersome insects in the lowlands. These areas also provided a natural sloping movement corridor from bottomland to uplands and bluffs. Unfortunately, very few remnant slope forest sites remain as most have been cleared for agriculture. Small remnant sites include the floodplain edge of Kissenger Hill and bluffs near Annada in Lincoln County, Missouri and floodplain bluff edges south of Elsberry, Missouri.

Prairies occupied extensive parts of the Mississippi River floodplain in the Cannon and Delair areas and likely a small upland area on the west side of Fox Island (Schroeder 1982, Nelson et al. 1998, Nigh and Schroeder 2002, Thogmartin et al. 2009). Most of these prairies were wet or wet mesic "bottomland" types, but smaller areas of mesic "sand-type" prairies occurred on higher elevation terraces and ridges such as at Fox Island (Allen 1870, Hus 1908, Sampson 1921, Turner 1934, Chmurny 1973, Gregg 1975, Benchley 1976, Patterson 1989, Nelson et al. 1994, 1998). Bottomland prairies often are described in older naturalist accounts as "slashy", "wet meadow", or even shallow "marsh" habitats (e.g., Oliver 1843). These bottomland prairies contain a variety of plant associations dominated by grasses and sedges depending on soil moisture conditions. Generally, bottomland prairies occupy elevations that flood at 2-5-year flood frequencies. Soils under bottomland prairies range from clay-silts in swales to silt loams or even sandy loams on ridges. Bottomland prairie "ridges" on point bars contain many grasses such as big bluestem, blue joint, and switch grass. Bottomland prairie "swales" include many sedges and wetland-type plants such as river bulrush, floating manna grass, bur reed,

Table 1. Long-term temperature data from 1971-2000 at Elsberry, MO (from www.ncdc.noaa.gov/oa/climate/normals/usnormals.html).

Temperature (˚F)																				
Mean (1)				Extremes										Degree Days (1) Base Temp 65		Mean Number of Days (3)				
Month	Daily Max	Daily Min	Mean	Highest Daily(2)	Year	Day	Highest Month(1) Mean	Year	Lowest Daily(2)	Year	Day	Lowest Month(1) Mean	Year	Heating	Cooling	Max >= 100	Max >= 90	Max >= 50	Max <= 32	Min <= 32	Min <= 0
Jan	39.1	18.6	28.9	78	1950	25	41.0	1990	-24+	1979	15	14.3	1977	1122	0	.0	.0	5.9	10.9	27.5	3.9
Feb	46.1	24.0	35.1	81	1932	10	44.4	1976	-24+	1979	9	19.5	1978	839	0	.0	.0	10.0	6.0	22.0	2.3
Mar	57.7	32.7	45.2	88	1986	29	52.4	1973	-14+	1978	5	37.5	1978	614	1	.0	.0	20.4	1.1	16.4	.2
Apr	69.5	42.5	56.0	94	1986	25	63.1	1981	16	1950	14	50.6	1983	288	18	.0	.5	27.9	.0	5.2	.0
May	78.1	51.9	65.0	102	1934	31	71.6	1991	28	1950	1	60.6	1981	111	112	.0	1.8	30.9	.0	.4	.0
Jun	86.4	61.2	73.8	107	1936	19	79.0	1971	38	1972	1	68.9	1982	7	271	.3	9.7	30.0	.0	.0	.0
Jul	90.4	65.6	78.0	116	1954	15	82.0	1980	40+	1975	13	74.3	1984	0	404	1.7	16.8	31.0	.0	.0	.0
Aug	88.4	63.5	76.0	110	1934	9	81.3	1980	39	1986	29	71.1	1992	4	343	1.3	11.8	31.0	.0	.0	.0
Sep	81.3	55.4	68.4	105	1984	1	73.0	1998	16	1931	7	63.4	1974	48	149	.2	4.8	30.0	.0	.2	.0
Oct	70.2	43.8	57.0	95+	1963	10	63.8	1971	14	1952	29	50.4	1976	270	22	.0	.2	30.2	.0	4.9	.0
Nov	55.9	34.5	45.2	88+	1950	2	51.8	1999	-7	1991	8	36.9	1976	595	0	.0	.0	19.1	.8	14.2	@
Dec	42.7	23.5	33.1	77	1948	15	40.8	1971	-23	1989	23	20.1	1983	989	0	.0	.0	8.1	7.0	24.8	1.6
Ann	67.2	43.1	55.1	116	Jul 1954	15	82.0	Jul 1980	-24+	Feb 1979	9	14.3	Jan 1977	4887	1320	3.5	45.6	274.5	25.8	115.6	8.0

sweetflag, duck potato, water parsnip, pickerel weed, water plantain, dock, smartweeds, spikerush, ditch stonecrop, common skullcap, monkey flower, and yellow water-crowfoot. They also contain abundant prairie cordgrass, marsh elder, sumpweed and asters at the transition zones between "ridge" and "swale." A few wetter-type bottomland prairie remnants occur on the Ted Shanks and B.K. Leach CA's and Cannon NWR in Missouri.

The distribution of bottomland prairie was determined by the dynamic "line" of where floodwater ranged toward higher elevations in floodplains vs. the "line" where fires originating from uplands and higher elevations moved into the wetter lowlands (Nelson et al. 1998, Nelson 2005, Heitmeyer and Westphall 2007, Heitmeyer 2008b, Thogmartin et al. 2009). Transition areas between bottomland prairie and forest in the Mississippi River floodplain, especially on terraces historically contained oak-dominated savanna. Historically, bottomland prairie and savanna vegetation was partly maintained by seasonal burning started by natural events (e.g., lightning strikes) and native people and also by herbivory from elk, bison, deer, and many rodents (e.g., Nelson 2005). This herbivory cropped and recycled prairie vegetation and also browsed invading woody shrubs and plants. Bottomland prairie supported many animal species and prairie swales that were seasonally flooded for short periods in spring and summer provided extensive foraging and breeding habitat for wetland-dependent birds and amphibians/reptiles.

In some higher elevation colluvial slopes bottomland prairie transitioned into more upland mesic-type prairie communities that often extended into uplands adjacent to the Mississippi River and tributary floodplains. These mesic prairie communities sometimes merged with slope forests on alluvial fans and upland/bluff margins. Mesic prairie was dominated by perennial upland type grasses including little bluestem, Indian grass, switchgrass, drop-stem, side-oats gramma, bunch grass, plains muhly, and panic grasses. Vegetation in mesic prairies often was 3-4 feet tall and during spring early travelers viewed these areas as a veritable flower garden (see descriptions in White 2000). Woody vegetation encroached on the upland edges of this prairie type and hazelnut, box elder, hickory, elm, and slope forest species were common. Fire likely sustained mesic prairies and bands of savanna also were present in some locations (Nelson et al. 1998). Given the position of mesic prairie and savanna, animal species common to both forest and prairie were present. These sites also were common camp or occupation sites for native peoples because of their higher, less flood prone, location; the presence of grasslands where small cultivation areas could be easily maintained; locally available wood for fires; and natural travel corridors between uplands and floodplains.

DISTRIBUTION AND EXTENT OF PRESETTLEMENT HABITATS

The exact distribution of vegetation communities (habitat types) at Cannon and Great River NWRs prior to significant European settlement in the late 1700s is not known. However, many sources of information about the geography and distribution of major vegetation communities are available for the region and they include historic cartography, botanical data and accounts, and general descriptions of landscapes from early explorers and naturalists (Heitmeyer 2007b, Laustrap and Lowenberg 1994, Sickley and Mladenoff 2007). While the precise geography of early maps (e.g. river channel boundaries) is often flawed, these maps provide

Table 2. Long-term precipitation data from 1971-2000 at Elsberry, MO (from www.ncdc.noaa.gov/oa/climate/normals/usnormals.html).

Precipitation (inches)																								
	Precipitation Totals									Mean Number of Days (3)				Precipitation Probabilities (1) Probability that the monthly/annual precipitation will be equal to or less than the indicated amount										
	Means/ Medians(1)		Extremes							Daily Precipitation				Monthly/Annual Precipitation vs Probability Levels These values were determined from the incomplete gamma distribution										
Month	Mean	Med-ian	Highest Daily(2)	Year	Day	Highest Monthly(1)	Year	Lowest Monthly(1)	Year	>= 0.01	>= 0.10	>= 0.50	>= 1.00	.05	.10	.20	.30	.40	.50	.60	.70	.80	.90	.95
Jan	2.01	1.44	2.22	1975	10	5.42	1995	.06	1986	8.4	4.7	1.0	.4	.23	.38	.66	.94	1.24	1.58	1.97	2.46	3.12	4.21	5.27
Feb	2.02	1.68	2.00	1959	10	5.25	1998	.45	1991	7.8	4.6	1.3	.4	.52	.71	1.00	1.26	1.52	1.79	2.09	2.44	2.91	3.64	4.33
Mar	3.54	3.24	3.12	1972	13	8.49	1973	.41	1971	9.6	6.7	2.4	.8	1.18	1.51	2.01	2.42	2.83	3.24	3.69	4.22	4.90	5.96	6.93
Apr	3.84	3.63	3.44	1994	12	11.56	1994	.89	1977	10.5	6.9	2.5	1.1	1.05	1.41	1.97	2.45	2.93	3.43	3.98	4.63	5.48	6.82	8.06
May	4.10	3.56	3.70	1981	10	9.32	1995	1.02	1972	10.8	7.7	2.7	1.0	1.02	1.41	2.00	2.53	3.06	3.61	4.23	4.96	5.92	7.44	8.86
Jun	3.45	2.62	4.40	1993	20	11.06	1993	.50	1992	8.7	6.2	2.3	.9	.65	.96	1.46	1.93	2.40	2.92	3.50	4.20	5.13	6.62	8.05
Jul	3.43	3.27	3.50	1962	4	8.77	1981	.67	1975	8.3	6.0	2.3	.9	.69	1.00	1.51	1.97	2.44	2.93	3.50	4.18	5.08	6.52	7.88
Aug	3.20	3.22	3.85	1946	16	6.39	1975	.27	1984	7.7	4.8	2.3	1.0	.62	.91	1.38	1.81	2.25	2.72	3.26	3.90	4.76	6.13	7.43
Sep	3.30	2.62	3.75	1973	9	11.12	1993	.13	1979	7.6	5.4	2.2	.9	.62	.91	1.40	1.84	2.30	2.79	3.35	4.02	4.91	6.35	7.71
Oct	2.84	2.56	4.50	1941	5	6.39	1976	.82	1992	8.3	5.6	1.9	.6	1.04	1.31	1.69	2.01	2.32	2.63	2.97	3.36	3.86	4.63	5.34
Nov	3.53	3.18	3.25	1946	1	10.54	1985	.40	1989	8.4	6.2	2.7	.9	.68	1.00	1.52	1.99	2.48	3.00	3.59	4.30	5.24	6.76	8.20
Dec	2.99	2.55	5.04	1982	3	11.57	1982	.46	1976	8.6	5.8	2.1	.8	.69	.97	1.40	1.80	2.19	2.60	3.07	3.63	4.36	5.52	6.62
Ann	38.25	37.36	5.04	Dec 1982	3	11.57	Dec 1982	.06	Jan 1986	104.7	70.6	25.7	9.7	26.13	28.44	31.42	33.70	35.73	37.70	39.75	42.01	44.77	48.79	52.28

Snow (inches)																							
Snow Totals															Mean Number of Days (1)								
Means/Medians (1)					Extremes (2)										Snow Fall >= Thresholds					Snow Depth >= Thresholds			
Month	Snow Fall Mean	Snow Fall Median	Snow Depth Mean	Snow Depth Median	Highest Daily Snow Fall	Year	Day	Highest Monthly Snow Fall	Year	Highest Daily Snow Depth	Year	Day	Highest Monthly Mean Snow Depth	Year	0.1	1.0	3.0	5.0	10.0	1	3	5	10
Jan	7.1	4.1	1	#	8.0	1987	9	27.7	1979	14	1979	7	8	1979	4.2	2.4	.7	.2	.0	3.6	1.7	1.1	.7
Feb	4.2	3.3	#	0	7.0	1993	25	12.1	1989	11	1978	28	9	1978	2.6	1.5	.6	.2	.0	1.0	.2	.0	.0
Mar	3.3	2.0	#	0	10.0	1989	6	15.8	1978	15	1978	5	6	1978	1.6	1.0	.4	.1	@	1.4	1.1	1.0	.6
Apr	.7	.0	#	0	3.5	1983	17	4.5	1983	3	1971	6	#+	2000	.4	.3	.1	.0	.0	.1	.1	.0	.0
May	.0	.0	0	0	.0	0	0	.0	0	0	0	0	0	0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Jun	.0	.0	0	0	.0	0	0	.0	0	0	0	0	0	0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Jul	.0	.0	0	0	.0	0	0	.0	0	0	0	0	0	0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Aug	.0	.0	0	0	.0	0	0	.0	0	0	0	0	0	0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Sep	.0	.0	0	0	.0	0	0	.0	0	0	0	0	0	0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Oct	#	.0	0	0	#	1993	31	#	1993	0	0	0	0	0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Nov	1.2	.0	#	0	6.0	1977	27	6.0	1977	5	1975	27	#+	1997	.5	.4	.2	@	.0	.2	.1	.1	.0
Dec	3.8	2.5	#	0	7.5	1973	20	15.0	1981	7	2000	14	3	2000	2.4	1.4	.5	.2	.0	1.7	1.2	.7	.0
Ann	20.3	11.9	N/A	N/A	10.0	Mar 1989	6	27.7	Jan 1979	15	Mar 1978	5	9	Feb 1978	11.7	7.0	2.5	.7	@	8.0	4.4	2.9	1.3

Table 3. Long-term freeze data from 1971-2000 at Elsberry, MO (from www.ncdc.noaa.gov/oa/climate/normals/usnormals.html).

Freeze Data									
Spring Freeze Dates (Month/Day)									
Temp (F)	**Probability of later date in spring (thru Jul 31) than indicated(*)**								
	.10	**.20**	**.30**	**.40**	**.50**	**.60**	**.70**	**.80**	**.90**
36	5/16	5/11	5/07	5/04	5/02	4/29	4/26	4/22	4/18
32	5/06	5/01	4/27	4/24	4/21	4/18	4/14	4/10	4/05
28	4/19	4/15	4/12	4/10	4/08	4/06	4/03	3/31	3/27
24	4/14	4/09	4/05	4/02	3/30	3/27	3/24	3/21	3/16
20	3/31	3/26	3/23	3/20	3/17	3/14	3/11	3/08	3/03
16	3/24	3/18	3/13	3/09	3/06	3/02	2/26	2/21	2/15
Fall Freeze Dates (Month/Day)									
Temp (F)	**Probability of earlier date in fall (beginning Aug 1) than indicated(*)**								
	.10	**.20**	**.30**	**.40**	**.50**	**.60**	**.70**	**.80**	**.90**
36	9/22	9/26	9/29	10/02	10/05	10/07	10/10	10/13	10/17
32	9/27	10/01	10/05	10/08	10/10	10/13	10/16	10/19	10/24
28	10/10	10/15	10/18	10/21	10/24	10/26	10/29	11/01	11/06
24	10/20	10/26	10/30	11/03	11/06	11/10	11/14	11/18	11/24
20	10/26	11/02	11/07	11/11	11/15	11/19	11/23	11/28	12/05
16	11/10	11/16	11/20	11/23	11/26	11/29	12/03	12/07	12/12
Freeze Free Period									
Temp (F)	**Probability of longer than indicated freeze free period (Days)**								
	.10	**.20**	**.30**	**.40**	**.50**	**.60**	**.70**	**.80**	**.90**
36	176	169	164	159	155	151	147	142	135
32	194	186	181	176	172	168	163	158	150
28	215	209	205	201	198	195	191	187	181
24	244	236	230	225	221	216	211	205	197
20	266	258	252	247	242	237	233	227	219
16	284	278	273	269	265	261	257	252	246

general descriptions of relative habitat types, distribution, and configuration.

Apparently, the first maps of the Mississippi River (and parts of its floodplain just north of St. Louis were made during French governance of the region by the French cartographers Franquelin (produced in1682) (Fig. 15), De L'Lsle (1703 and 1718), d'Anville (1746 and 1755), and Bellin (1755) (Wood 2001). When the British Regime succeeded French rule of the area in the mid-1700s, new maps of the Mississippi River corridor were prepared. The first known British map was drawn by Philip Pitman in 1765 and it essentially was a compendium of the earlier French maps (Thurman 1982). Although it was not highly original, the Pittman map became the accepted "standard" for geography of the southern part of the region; subsequent maps expanded coverage and descriptions to lower course tributaries (e.g., the Ross map produced in 1867) and floodplains (Hutchins 1784). The Hutchins' map relied heavily on Pitman's map and his book "A topographic description of Virginia, Pennsylvania, Maryland, and North Carolina" published in 1778 contained the most accurate map of the Illinois Country at that time. The journal from Hutchins' mapping trip and that of Captain Harry Gordon at the same period offered detailed description of many important floodplain features. Subsequent to Hutchins' map was the excellent map of General Victor Collot prepared from field surveys in the late 1790s and published in 1826. This "Collot" map provided expanded notes and coverage of vegetation and larger wetlands in the Mississippi River floodplain and became the basis for additional maps and naturalist accounts of Nicolas de Finiels in the early 1800s (Ekberg and Foley 1989).

In the early 1800s, following American occupation and rule, the entire UMRS was mapped by the U.S. General Land Office (GLO) to establish a geometric system of land ownership and governance (i.e., the Range-Township-Section system developed by Thomas Jefferson and codified in the Land Survey Ordinance of 1785). These GLO surveys established right-angle "section lines" in a geometric land grid

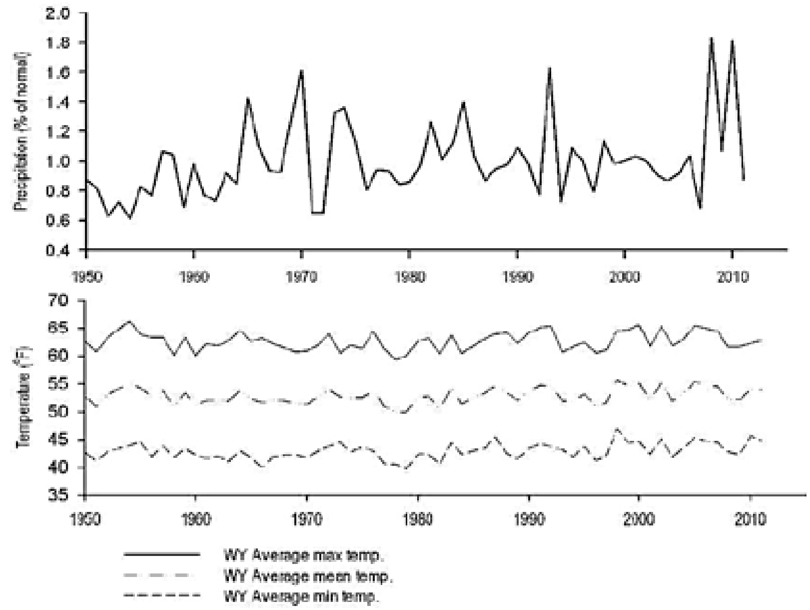


Figure 7. Water year (1 October to 31 September) percentage that annual precipitation deviates from normal (1=typical and 2=200% of normal) from 1950 to 2011 at Bowling Green, MO (from Newman 2012).

system, and the surveyors also documented vegetation and "witness" trees at section corners and center points between the corners (GLO 1817, 1821). Consequently, the GLO maps and surveys established a "georeference" of locations and distribution of QCA features including general habitat types. GLO surveyors usually described vegetation communities in broad categories (e.g., forest, bottomland, and prairie) and grouped witness trees in general taxonomic groups (e.g., black vs. white oak). Consequently, considerable interpretation often is needed to determine the exact species composition that was noted (Bourdo 1956, Hutchinson 1988, Schulte and Mladenoff 2001). Most likely, the "black oaks" described in GLO notes for the QCA were pin oaks (e.g., Nelson et al. 1998) and the "white oaks" probably were swamp white or even some overcup oak. GLO notes that describe general habitat types of forest, bottomland, prairie, open water, etc. do not describe composition of forests nor do they delineate small areas of trees or herbaceous wetlands within bottomland settings (Bourdo 1956, Hutchinson 1988). GLO surveys probably mapped savannas as forest, but this is unclear because many savanna areas may have contained larger amounts of prairie or other grasses. In the Cannon-Great River region, GLO notes and maps often mix the terms "bottomland", "woodland", and "forest" (Fig.. 13). Most "bottomland" categories in the Cannon-Great River region appears to have been floodplain forest or bottomland prairie communities, however, the scale of mapping, and definition of communities often is gross and inconsistent. Further, GLO notes suggest travel through, and precise documentation of, vegetation in low elevation, wet, floodplain locations (such as abandoned channels and floodplain depressions) was difficult and somewhat cursory. Notes in these areas often refer to lands simply as "water", "wet", "swampy", "marais", or "flooded."

In addition to the GLO surveys, many other cartographers, naturalists, and explorers produced maps (often small- scale maps of a local area) and provided natural history accounts and botanical records for many UMRS areas including sites at or near Cannon and Great River NWRs (Hutchins 1784, Brackenridge 1814, Schoolcraft 1825, Flint 1828, Flagg 1838, Wild 1841, Oliver 1843, Featherstonhaugh 1844, Warren 1867, Allen 1870, Brink and Co. 1875). In 1879, the Mississippi River Commission (MRC, 1881) produced the first complete set of maps for the Mississippi River from New Orleans to Minneapolis. This map set included detailed descriptions of the Mississippi River channel, side channels and chutes, tributaries, floodplain habitats (general habitat types), floodplain lakes, and settlements (see Appendix maps in Heitmeyer and Bartletti 2012). Other maps made in 1890 and the early 1900s documented landscape changes and river geomorphology (e.g., Brown 1931, Brauer et al. 2005).

Recognizing the caveats of the GLO surveys, vegetation communities in the Great River NWR region historically were dominated by wet and wet-mesic bottomland prairie; deeper floodplain wetland depressions that contained emergent and perennial herbaceous marsh-type vegetation usually surrounded by shrub/scrub vegetation; and bottomland hardwood, floodplain, riverfront, and slope forest communities. Analyses of Presettlement vegetation communities at the time of the GLO surveys beginning in the early-1800s indicate most of Cannon was a bottomland prairie/marsh complex with a narrow band of floodplain and riverfront forest bordering the Mississippi River (Fig.

13). Delair Division also contained bottomland prairie habitats in the north part of the area with forest bordering the Sny and Mississippi River channels. The major lakes and sloughs at Delair supported zones of wetland vegetation ranging from open water/aquatic in the deeper center areas grading to herbaceous moist-soil and shrub/scrub communities on the margins of the lakes and sloughs. Long Island historically was covered with riverfront and floodplain forest interspersed with side channel and chute aquatic habitats. Similarly, Fox Island was predominantly forested with some possible savanna and sand prairie present on the far northwest side.

Collectively, the above maps, historical accounts, and published literature suggest historical vegetation communities in the Cannon-Great River region were distributed along elevation, geomorphology, and hydrological gradients (Table 5). Similar community distribution associations also occur in other Mississippi Valley floodplain areas and help validate information from the region (e.g., Sparks 1993, Heitmeyer and Westphall 2007, Heitmeyer 2008a, b; Heitmeyer 2010). Relationships between community types and geomorphology, soils, topography, and flood frequency zones were used to prepare HGM matrices that identified the potential distribution, composition, and area of Presettlement habitats for the

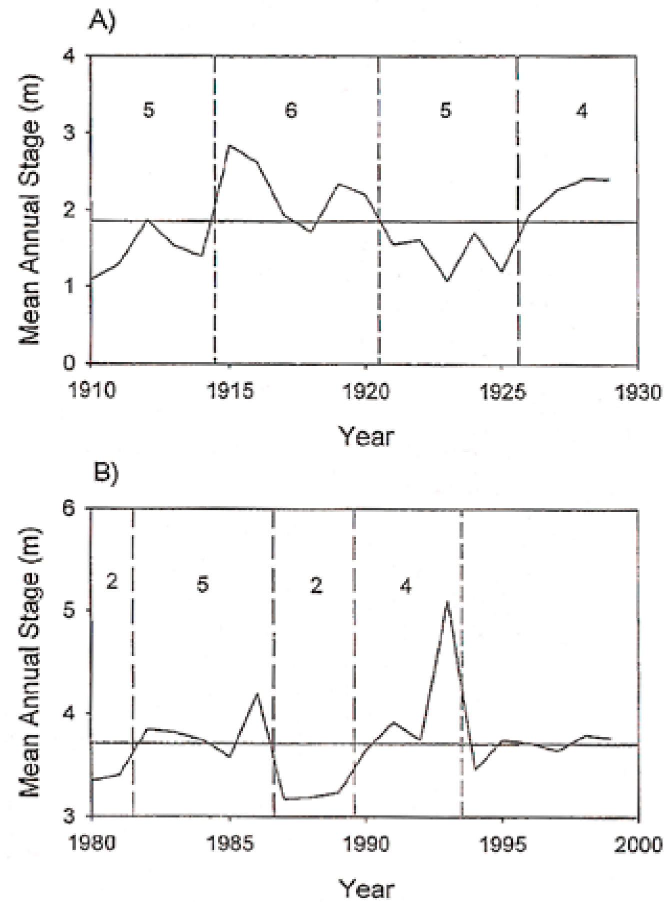


Figure 8. Mean annual stage of the Mississippi River at Hannibal, MO, a) 1910-1929 and b) 1980-1989. Horizontal line is the mean for the period. Vertical lines are changes between high and low flow periods; numbers represent years of high or low flows (from Franklin et al. 2003).

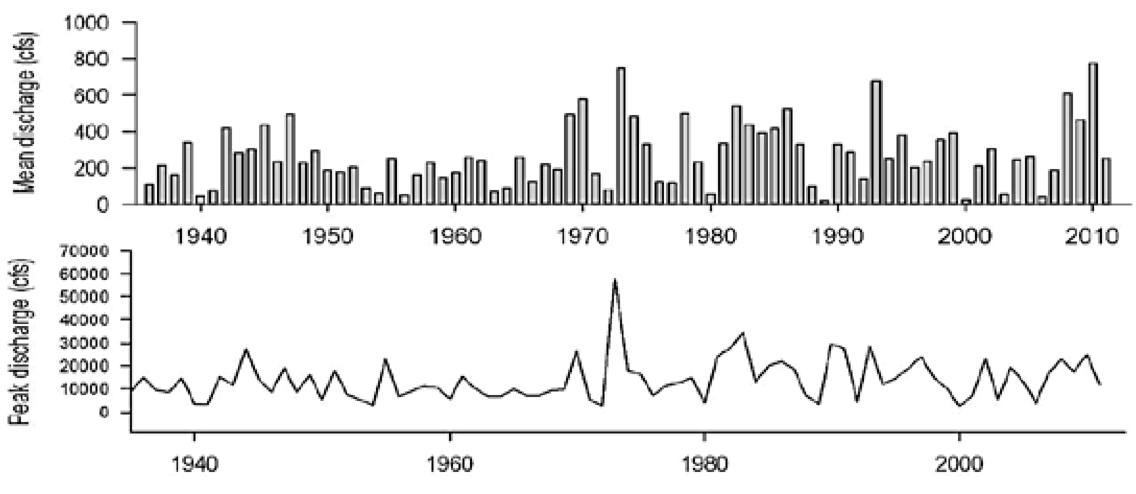


Figure 9. Mean annual and peak discharge for the North River at Palmyra, MO from 1935 to 2011 (from Newman 2012).

Cannon-Great River region (Table 5). The methods of determining these relationships involved the following steps of overlaying data layers from historical and current maps and then validating relationships using field reference sites (see Klimas et al. 2005, 2009, Heitmeyer 2007a, Heitmeyer 2008a, Heitmeyer 2010, Heitmeyer et al. 2013b for specific methodology):

Figure 10. Peak discharge for the Fox River at Wayland, MO from 1935 to 2010 (from Newman 2012).

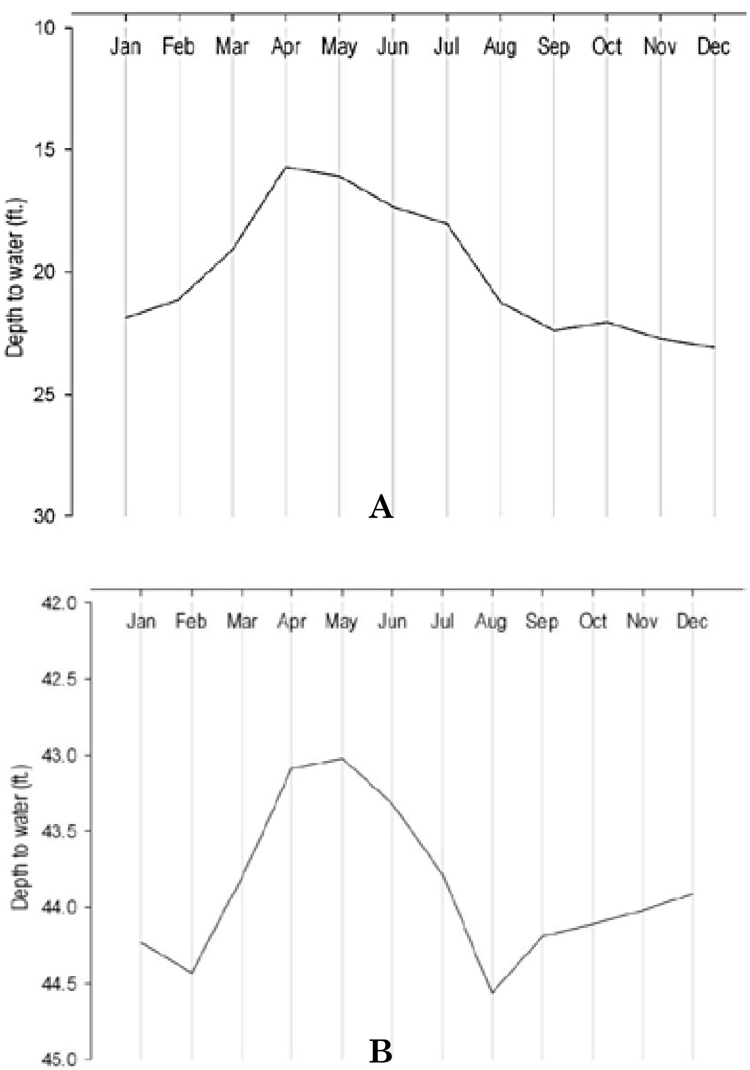


Figure 11. Mean groundwater level for: a) near Hannibal, MO 1957-2011 and b) near Wayland, MO 1983-2010 (fro Newman 2012).

1. General habitat type maps (e.g., forest, prairie, bottomland lake) determined from GLO surveys (Fig. 13) and historic cartography (e.g., Hutchins 1784, Collot 1826, De Finiels maps from the 1800s in Ekberg and Foley 1989, Mississippi River Commission 1881) were overlain on contemporary geomorphology (Bettis et al. 1996, 2008; Hajic 2000; Woerner et al. 2003; Brauer et al. 2005), soils (Fig. 4) and elevation (Fig. 5) maps. Mississippi River stage-discharge recurrence data (Table 6) also were used to determine frequency of flooding where subtle differences in island and floodplain topography likely influence the presence of either early succession riverfront or less flood tolerant floodplain forest communities.

2. The general correspondence of communities with the abiotic geomorphology, soils, topography layers was determined where possible (see also Theiling et al. 2012). Confidence in this "map" correspondence was best when geo-referenced digital maps are available, such as the GLO surveys, and was weakest when older maps and cartography are used. Despite the imprecision, analyzing habitat information from the older maps provided useful information to determine the general distribution of communities. Using this first-step overlay of map information, relationships between communities and abiotic factors sometimes become clearly defined by one factor.

3. Remnant native vegetation communities were identified from aerial photographs and were visited to determine if they matched community types predicted from # 2 and to document vegetation characteristics, such as species composition. If the historic map and contemporary field data were consistent, then the field sites were considered a reference site of former community types (Nestler et al. 2010).

4. Major community types (e.g., forest, prairie) were subdivided into ecologically distinct sub-communities using botanical information for the respective communities

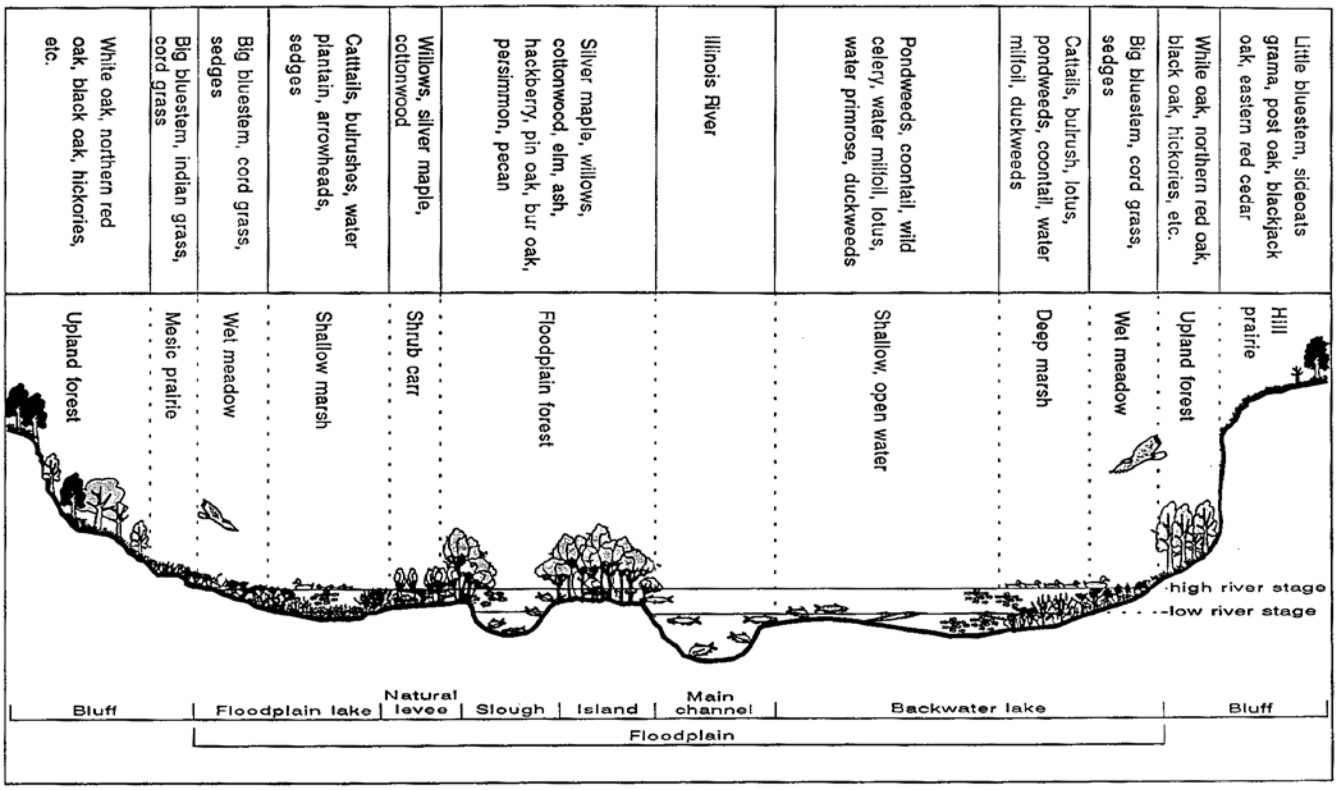


Figure 12. Cross-section of habitat types typical in Mississippi and Illinois river valleys (from Sparks 1993).

Table 4. Classification schemes of habitats found within the refuge.

Broad Habitat Types	Mark Twain CCP Habitats	Heitmeyer and Westphall (2007)	National Vegetation Classification Standard	Nelson (2005) Terrestrial Natural Communities of Missouri
Open Water	Open Water	Mississippi River channel and islands	Mississippi River channel and its associated tributaries and backwaters	Large Riverine
		Backwater sloughs and river side channels and chute		
Freshwater Wetlands	Permanently flooded submergent	Bottomland "oxbow" lakes	Midwest ephemeral pond	Marsh riverine wetland
	Semi-permanently flooded emergent		Bulrush - cattail - bur-reed shallow marsh	
			River bulrush seasonally flooded herbaceous alliance	
	Temporary and Seasonally flooded emergent		Smartweed species seasonally flooded herbaceous alliance	Marsh riverine wetland (Subtype annual plant species) aka **moist-soil unit**
	Scrub/Shrub	Shrub/scrub	North-central interior wet meadow-shrub	Shrub swamp riverine wetland aka **shrub/scrub**
Floodplain Forests	Wet floodplain forest	Riverfront forest	Eastern cottonwood temporarily flooded forest alliance	Riverfront forest
		Floodplain forest	Bur oak (white oak, northern pin oak, black oak) woodland alliance	Wetland bottomland forest
				Wet-mesic bottomland woodland
	Mesic bottomland forest		Sugar maple - oak - bitternut hickory mesic bottomland forest	Mesic bottomland forest
				Mesic bottomland woodland
Prairie/Grasslands	Wet meadow	Bottomland prairie	Prairie Cordgrass - Sedge species - Bluejoint - Winged Loosestrife - (Common Water-dropwort) Herbaceous Vegetation	Wet bottomland prairie
		Mesic prairie	Big Bluestem - Switchgrass - Sawtooth Sunflower Herbaceous Vegetation	Wet-mesic bottomland prairie

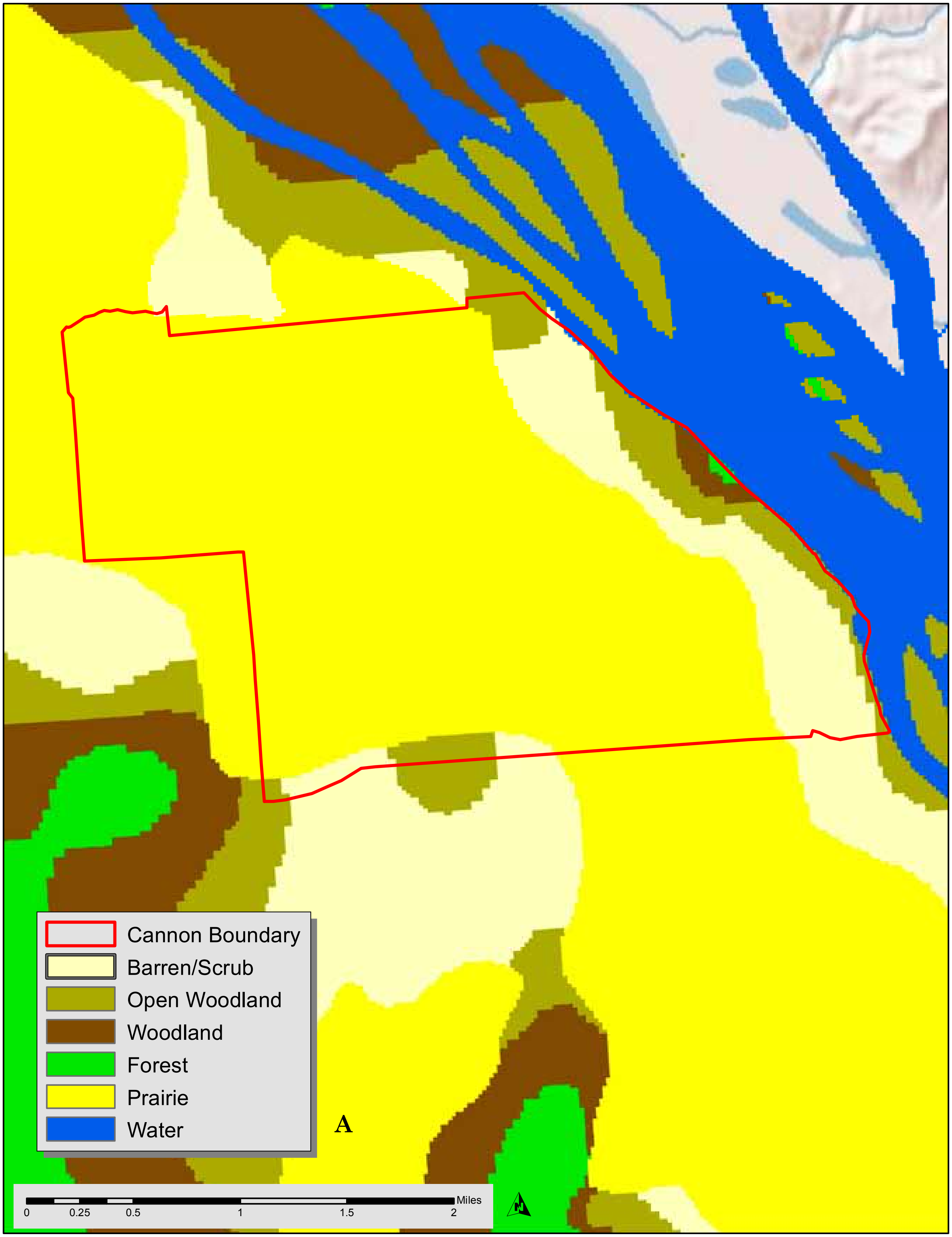


Figure 13. Generalized vegetation community type maps based on early-1800s General Land Office (GLO) surveys for: a) Clarence Cannon NWR, b) Delair unit, and c) Long and Fox Island units of Great River NWR.

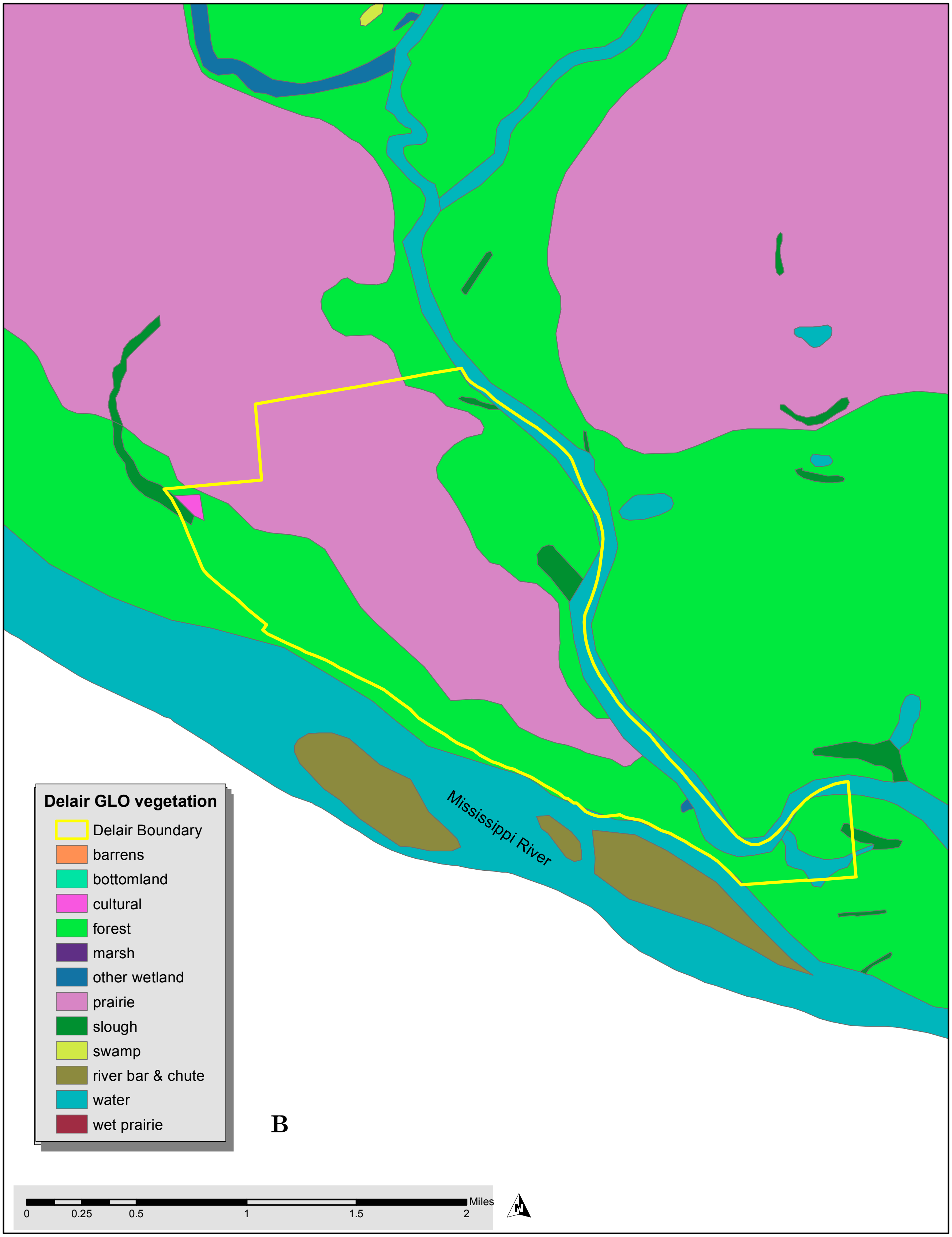


Figure 13, continued. Generalized vegetation community type maps based on early-1800s General Land Office (GLO) surveys for: a) Clarence Cannon NWR, b) Delair unit, and c) Long and Fox Island units of Great River NWR.

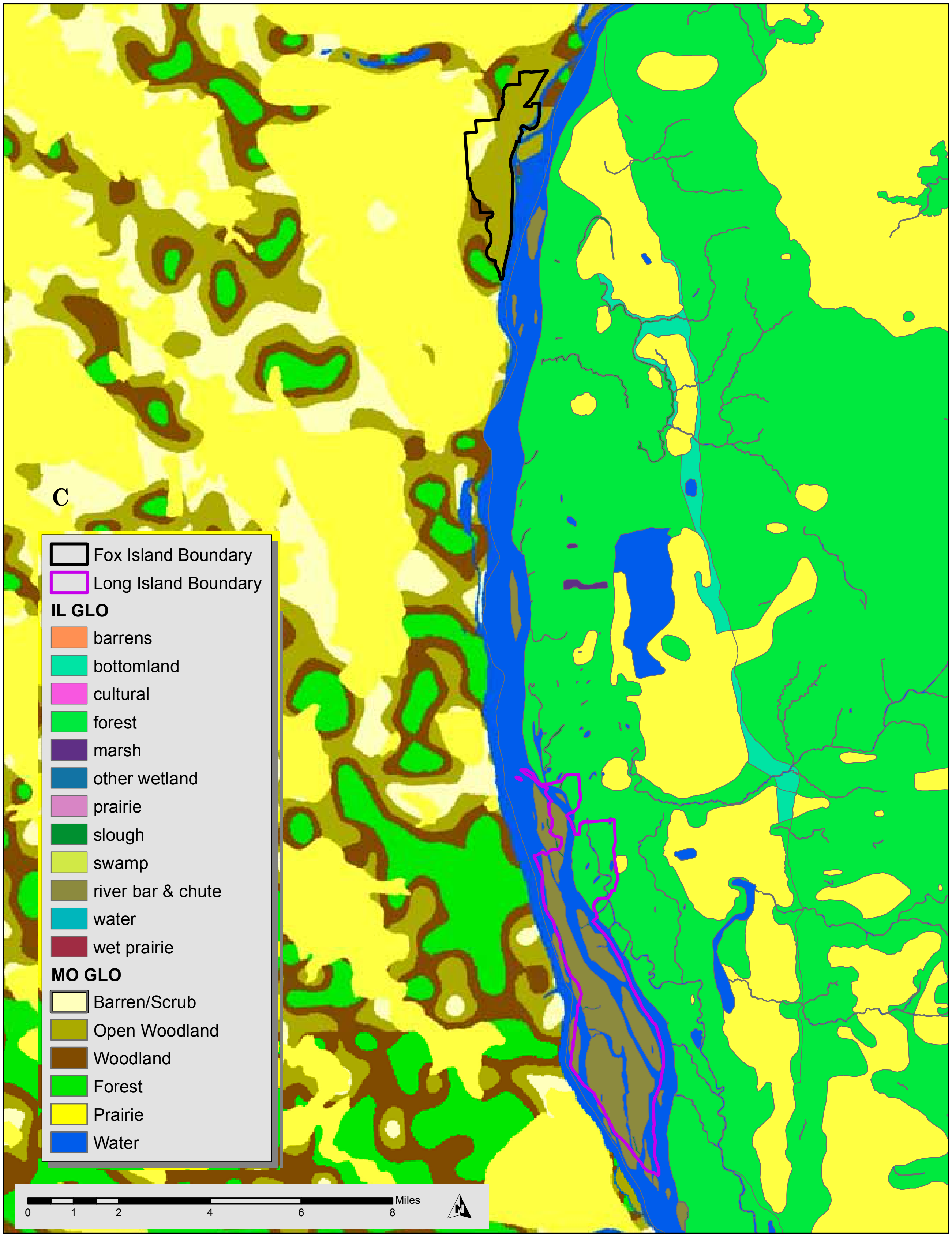


Figure 13, continued. Generalized vegetation community type maps based on early-1800s General Land Office (GLO) surveys for: a) Clarence Cannon NWR, b) Delair unit, and c) Long and Fox Island units of Great River NWR.

Table 5. Hydrogeomorphic (HGM) matrix of historical distribution of major vegetation communities/habitat types in the Cannon-Great River NWR region in relationship to geomorphic surface, soils, and hydrological regime. Relationships were determined from land cover maps prepared for the Government Land Office survey notes taken in the early 1800s, historic maps and photographs, U.S. Department of Agriculture soil maps, land sediment assemblage maps, flood frequency data provided by the U.S. Army Corps of Engineers; and various naturalist/botanical accounts and literature.

Habitat Type	Geomorphic Surface[a]	Soil Type[b]	Flood Frequency
Open Water/Aquatic	SC, SL, AC	Sand-gravel	Permanent
Persistent Emergent (PEM) and Seasonal Herbaceous	AC, SL	Silt loam, muck	Semi-permanent
Shrub/scrub (S/S)	Edges of AC, SC, and SL	Silt clay	Semi-permanent
Bottomland Prairie	CS, GT, NL, HMBO	Loam	> 5 year
Sand Prairie	GT	Loamy sand	> 5 year
Riverfront Forest	HMBN, AC, MCI	Sandy-silt	1 year
Floodplain Forest	HMBO, HMBN, TF	Silt loam-clay	2-5 year
Bottomland Hardwood Forest (BLH)	NL, TF, HMBO, YMB	Silt clay	> 5 year
Slope Forest-Savanna	CS	Mixed erosional	> 20

[a] AC – abandoned river channel oxbows and depressions, CS – alluvial fan and colluvial slope, GT – glacial terrace, HMBO – older Holocene meander belt, HMBN – recent Holocene meander belt, MCI – main channel island, NL – natural levee, SC – side channel, SL – sloughs-lakes-river channels, TF – tributary fan, TMB – tributary meander belt, YMB - Yazoo meander belt along the Sny River.

[b] Specific soil types associated with habitats on specific refuge areas are as follows: 1. Cannon: (savanna – Dupo, Moniteau), (wet-mesic bottomland prairie-Chequest, Twomile), (wet bottomland prairie – Carlow), (S/S and PEM/Seasonal herbaceous – Water on soil maps), (floodplain forest – Blackoar, Klum), (riverfront forest – Dockery). 2. Delair: (wet-mesic bottomland prairie – Petrolia, Coffeen, Ceresco), (S/S and PEM/seasonal herbaceous – Water on soil maps), (floodplain forest – Titus, Wakeland), (riverfront forest – Ambraw, Zumbro, Sarpy), (BLH – Darwin, Beaucoup). 3. Long Island: (riverfront forest – Blake-Slacwater), (floodplain forest – Blake-Slacwater and Ravenwash). 4. Fox Island: (sand prairie – Perks), (S/S – Zook), (riverfront forest – Gifford, Klum, Wakeland), (floodplain forest – Fatima, Huntsville, Beaucoup), (BLH – Colo).

where possible. For example, prairie consists of wet bottomland and drier mesic types (Nelson 2005). Botanical literature indicates that bottomland prairie typically occupied clay type soils within the 2-5 year floodplain (e.g., Turner 1934, Nelson et al. 1998, Nelson 2005, Heitmeyer and Westphall 2007). In contrast, mesic prairie occurred on higher elevation Pleistocene terraces and upper colluvial slopes that had mixed silt loam soils (e.g., Chmurny 1973, Gregg 1975, Nelson 2005).

5. A matrix of predicted community types in relationship to the geomorphology, soils, topography, and flood frequency variables discovered in steps 1-4 above was prepared (e.g., Table 5).

6. The position of predicted communities from the HGM matrix on the composite digital georeferenced maps of geomorphology, soils, topography, and flood frequency for the refuge areas was mapped where possible (note the caveats stated in #4 above).

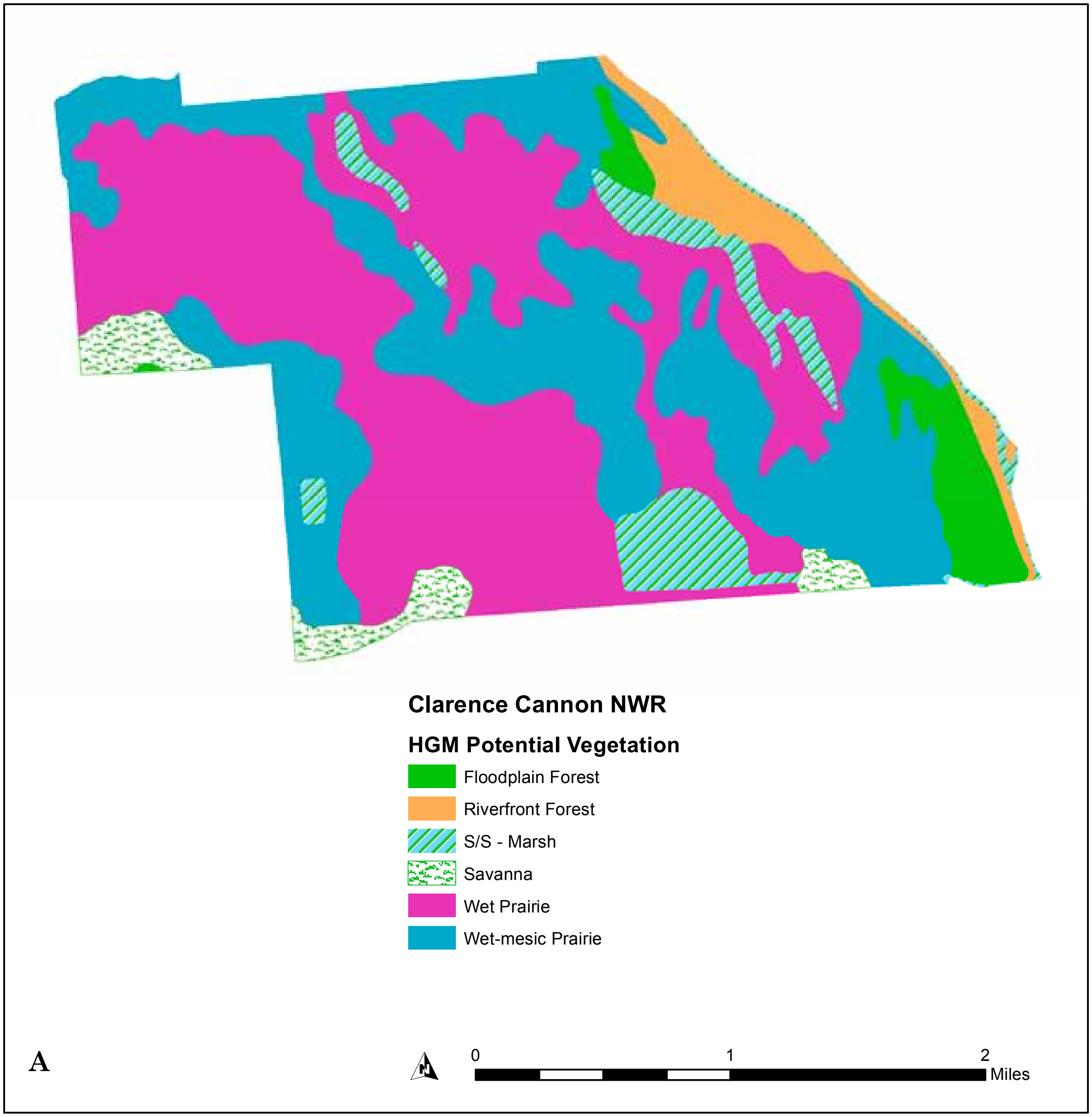


Figure 14. Potential distribution and types of vegetation communities present during the Presettlement period for: a) Clarence Cannon NWR, b) Delair unit, c) Long Island unit, and d) Fox Island unit of Great River NWR. Map prepared based on HGM attributes presented in Table 5.

7. Aerial photographs were used to identify remnant habitats of the refined community types (i.e. distinct prairie and forest communities) and reference sites and remnant habitats were revisited to determine what vegetation was present. This field data collection was similar to step #3 in finding reference sites that represent various communities. Specific reference sites that were visited in September-November 2011 in preparation of the HGM report for the Quincy, Sny, and Columbia-American Bottoms ecoregions (Heitmeyer and Bartletti 2012) were:

Pool 24

- Area along the Sny River in the Halfmoon Lake area on Delair NWR

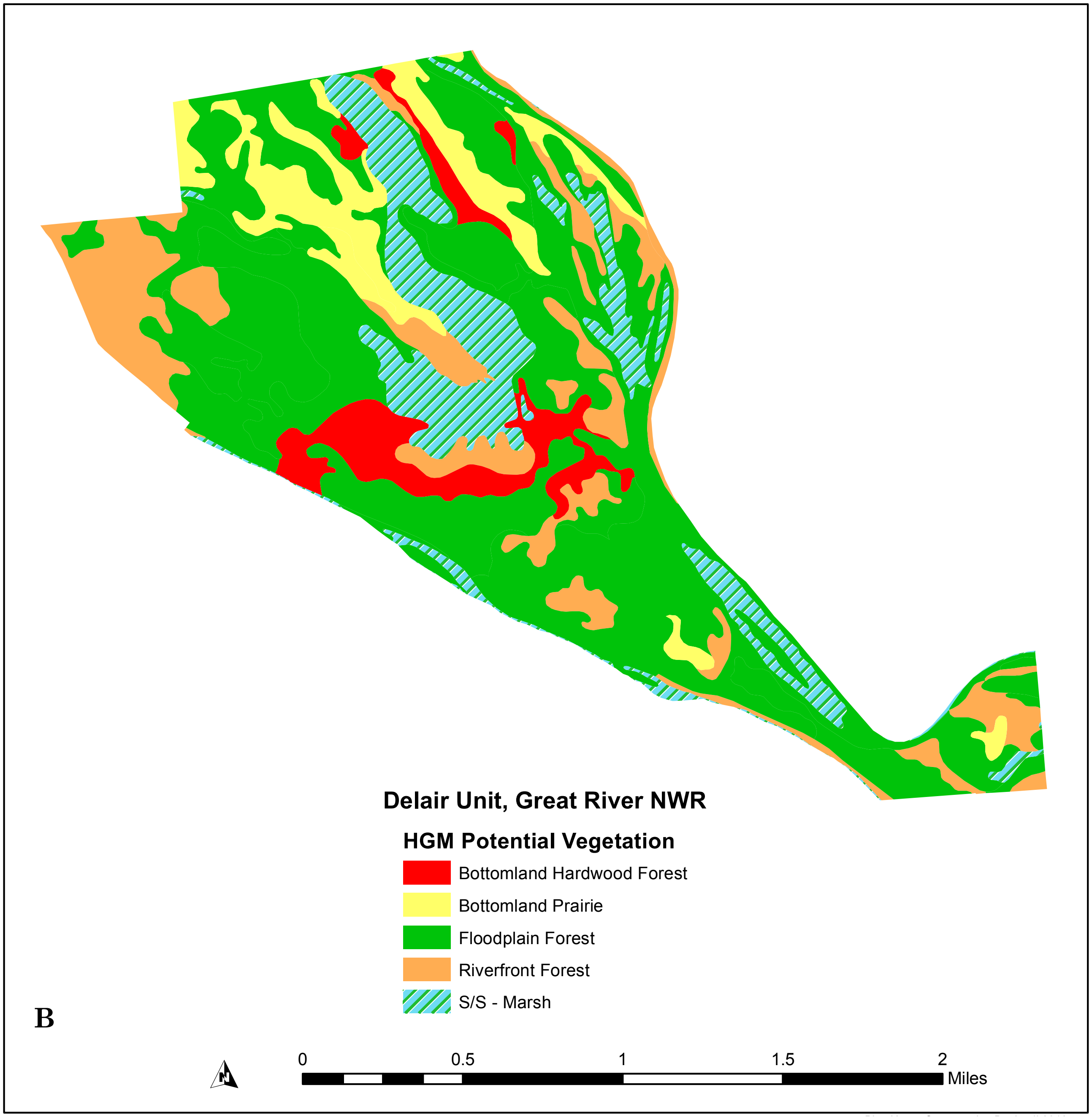


Figure 14, continued. Potential distribution and types of vegetation communities present during the Presettlement period for: a) Clarence Cannon NWR, b) Delair unit, c) Long Island unit, and d) Fox Island unit of Great River NWR. Map prepared based on HGM attributes presented in Table 5.

- Perry Pond and Nose Slough areas on Ted Shanks CA, Pike County, MO

Pool 25

- Rip Rap Landing State CA, Calhoun County, IL
- Fox Creek drainage, R1E and R2E – T53N, north of Clarence Cannon NWR
- Nelson Pond and Middle Slough areas, north of Stump Lake, Calhoun County, IL
- Prairie Slough CA, MO

8. The predicted potential Presettlement community distribution was mapped for each refuge area (Fig. 14).

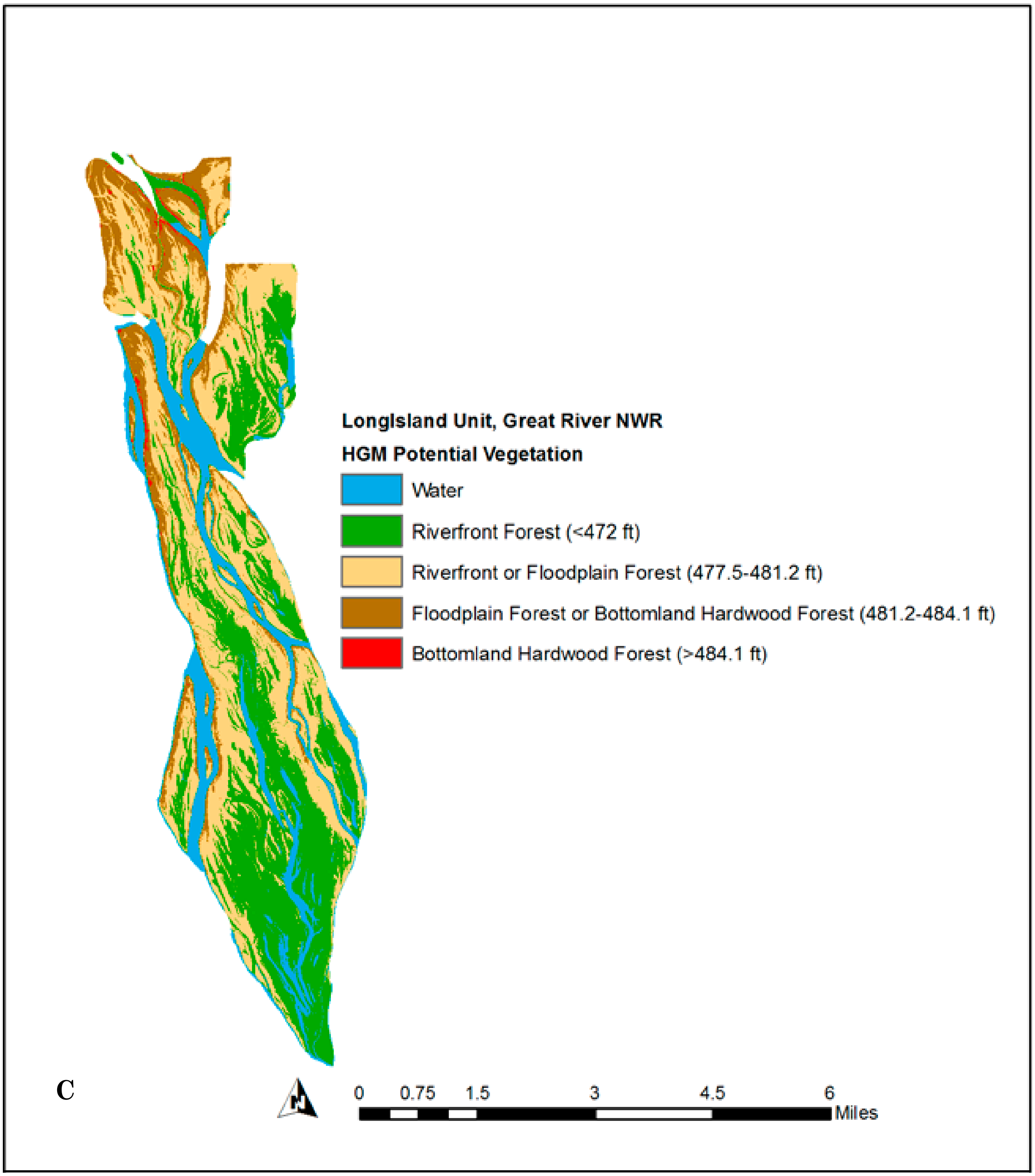


Figure 14, continued. Potential distribution and types of vegetation communities present during the Presettlement period for: a) Clarence Cannon NWR, b) Delair unit, c) Long Island unit, and d) Fox Island unit of Great River NWR. Map prepared based on HGM attributes presented in Table 5.

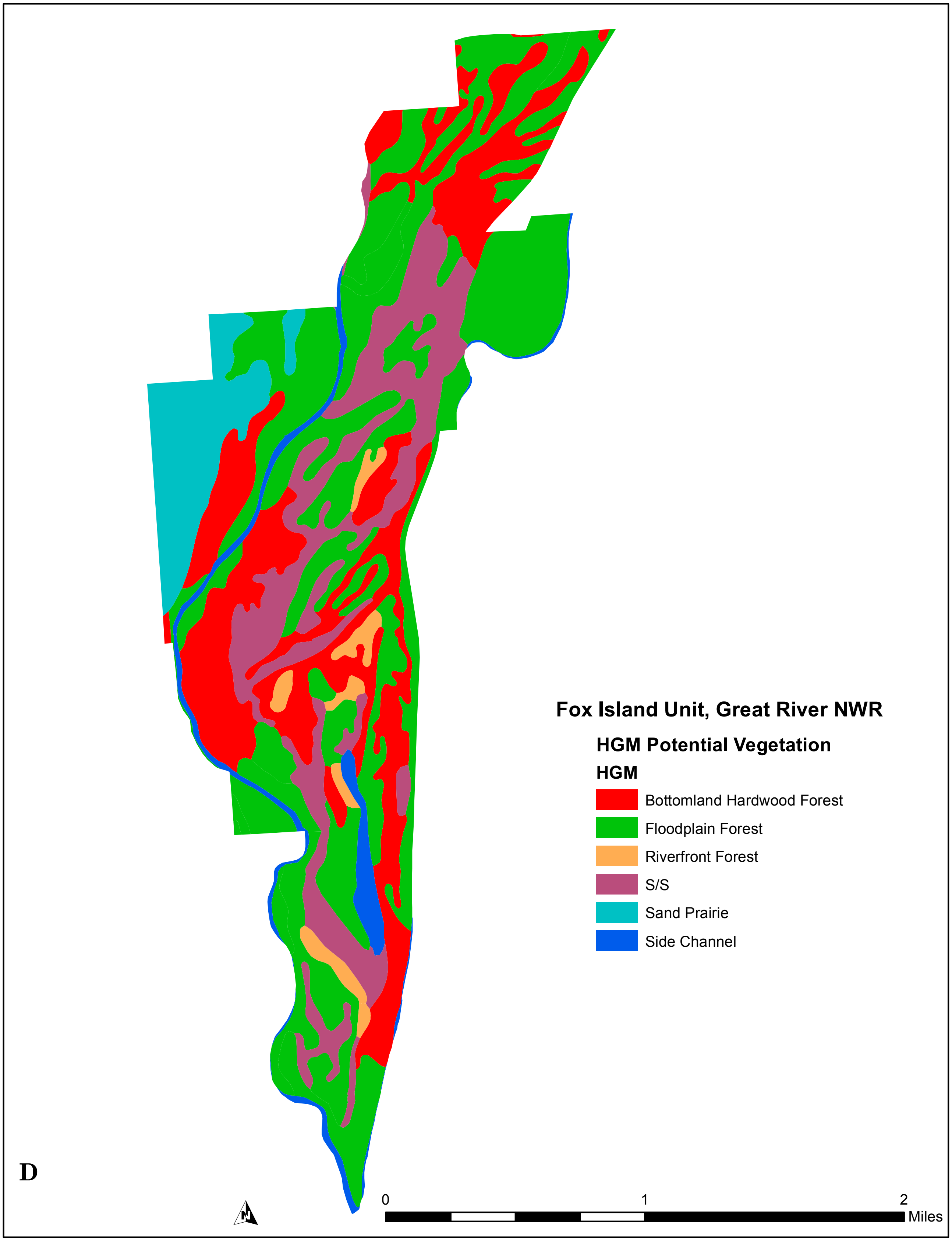


Figure 14, continued. Potential distribution and types of vegetation communities present during the Presettlement period for: a) Clarence Cannon NWR, b) Delair unit, c) Long Island unit, and d) Fox Island unit of Great River NWR. Map prepared based on HGM attributes presented in Table 5.

In summary, bottomland prairie historically occurred in contiguous bands in the higher floodplain elevations along alluvial fans and colluvial slopes, old remnant Pleistocene and Holocene terraces, and older Holocene channel belts filled with alluvial silt loam soils. The largest area of this prairie was at Cannon NWR. At higher elevations of slopes and fans, some mesic prairie likely occurred as continuums with upland prairies, such as on the west side of the Fox Island Division. Riverfront forest historically was present along the active Mississippi River channel especially on islands and bars where newly deposited sands and gravel were present. All refuge areas contained at least some of this forest type. Floodplain forests were interspersed throughout floodplains mainly on newer Holocene channel belts, while oak and pecan-dominated BLH forests were present along the historic Sny River channel and a few high elevation sites on Fox Island. Likely a small area of mixed slope forest-bottomland prairie savanna was present on the west side of Cannon NWR on the bottom end of an alluvial fan

The Cannon-Great River region had many scattered backwater areas created mainly by abandoned channels of the Mississippi River that supported diverse shrub/scrub, aquatic, and emergent/herbaceous wetland type communities. Generally, the highly dynamic river flow regimes of the Mississippi River along with the larger Fox and Sny rivers regularly scoured and deposited sediments and remnant abandoned channels often have complex geomorphic stratigraphy. The larger Swan Lake complex on Delair is an example of this bottomland lake setting and the Rabbitears and Big Pond areas on Cannon also represent floodplain depressional marsh and S/S type habitat.

Karen Kyle

CHANGES TO THE CANNON-GREAT RIVER NWR REGION

SETTLEMENT AND EARLY LANDSCAPE CHANGES

Detailed information on the settlement and changes to the Mississippi River Valley are available in many sources (see e.g., Theiling et al 2000, West Consultants, Inc. 2000, Heitmeyer and Bartletti 2012). Brief summaries of this information as is specifically relates to the Cannon-Great Rivers NWR region are provided below.

Occupancy of the Mississippi River Valley by native people dates to about 10,000 years BP (Chapman 1975, Farnsworth 1976, Hudson 1976, Bauxer 1978, Stoltman 1983). Documentation of various occupations including their distribution and use of resources prior to arrival of European people in the early 1600s is available in many archaeological reports and publications and short summaries are provided in Heitmeyer and Westphall 2007, Heitmeyer 2008a, b; and Heitmeyer 2010).

Generally, early people in the UMRS were nomadic and they relied heavily on hunting large mammals and gathering native plant foods and they established few permanent village and camp sites. By about 8,000 BP, most of the UMRS was occupied by at least some people and during the Altithermal 4,000 to 8,000 years BP, the region became warmer and drier, which apparently facilitated expansion of prairie and savanna communities into the region on remnant post-Wisconsin age glacial terraces, alluvial fans and colluvial slopes, and other higher drier elevation floodplain and upland bluff areas. At this time native people appear to have been congregated at a limited number of high elevation locations near permanent water areas of floodplain lakes and rivers. The Late Archaic period from 3,000 to 500 years BP was a time of great expansion of native human populations at numerous sites in the Cannon-Great River region as climate ameliorated. At this time, cultural elaboration caused settlements to become more specialized and organized. The early Woodland period from 2,100 to 2,500 years BP marked initial use of ceramics and horticulture expanded including some relatively expansive maize production sites. The Havana culture was strongly established along the Illinois River during this time and was part of an extensive trade network with people from northern Great Lakes areas. The large Cahokia Village east of St. Louis greatly enlarged about 800 to 900 BP (Milner 1998) and marked the final climax of native cultural development and large populations in the central part of the Mississippi River region. At this time, native populations expanded throughout the UMRS, many villages and settlements occurred along the river, a strong emphasis was placed on agricultural production, earthworks were constructed and inter-regional exchange of items was common. A general abandonment of the larger Mississippian villages occurred after 1550 and populations dispersed and relocated (Brose 1978). By 1600, much of the Upper and Middle Mississippi River Valley was depopulated because of conflicts among tribes and disease that coincided with the arrival of the first European explorers and settlers.

The Protohistory period 1540-1673 is generally considered to have the first appearance of Europeans in the southeastern U.S. and eventually into the UMRS. French explorers first reached the Great Lakes in 1615 and reached western Lake Superior by the 1660s bringing with them missionaries and markets for furs (Lanegran and Mosher-Sheridan 1983). When Marquette and Jolliet descended the Mississippi River in summer 1673, few native people were encountered in the UMRS (Marquette 1854).

The historic village of Cahokia was established in 1699 as a mission to remnant native people and became the first permanent "Euro-American" settlement on the Mississippi River. French traders erected and occupied over 10 forts on the Upper Mississippi River and its tributaries (Lanegran and Mosher-Sheridan 1983), but France eventually lost influence in the UMRS during the 1750s during the French and Indian War and in Europe during the Seven Years' War. By the early 1760s, France had lost its territory east of the Mississippi River to Britain and its territory west of the Mississippi River to Spain. The city of St. Louis was founded in 1764 and all early settlements in the region were on or near the Mississippi River. France regained the Louisiana Territory west of the Mississippi River in 1800 by treaty, but sold the territory in 1803 to the United States as the Louisiana Purchase. In the Cannon-Great River region, the towns of Clarksville, Louisiana, Hardin, Batchtown, Elsberry, Hannibal, and Quincy all were established in the early 1800s.

In 1805 Zebulon Pike, a lieutenant in the U.S. Army, made one of the first attempts to assert jurisdiction over the UMRS and he traveled up the Mississippi River to the confluence of the Mississippi and Minnesota rivers and bought land from local Sioux tribes. Western lands were considered "conquered" and available for settlement by U.S. citizens, although some land was allotted to conquered Indian inhabitants. Agreements between the U.S. government and native people usually were in the form of treaties and land cessions. Among these agreements was an 1804 treaty in which the Sauk and Fox tribes relinquished claims to land east of the Mississippi River, a treaty which prompted an unsuccessful Indian rebellion – the Black Hawk War – in 1832. Early descriptions of the Cannon-Great River region from early explorers including Marquette, Joliet, Pike, and Beck (1823), Brackenridge (1814), described the region as vast complexes of prairie, floodplain forest, and interspersed backwater lakes and sloughs that were relatively free of human influence. GLO surveys conducted in 1816 indicated few European settlements or land clearing (Nelson et al. 1998).

The City of St. Louis developed into a primary trading post in the Mississippi River Valley following the advent of steamboats in the early 1800s and rapid expansion of European populations and settlements occurred during the 1840 to 1860 period; by 1860 the population of St. Louis had increased to 160,000, making it the largest central U.S. city (Brauer et al. 2005). Reduced conflicts with northern native tribes and steamboat commerce led to increased settlement along the Mississippi River north to St. Paul and Minneapolis, Minnesota (Hartsough 1924). This mid-1800s settlement marked the beginning of conversion of prairies in the Cannon-Great River region for agricultural production, clearing of forests for lumber and fuel for steamboats, establishment of grain markets and river commerce, and gradually construction of rail lines and roads throughout the region. By the late 1850s, hundreds of thousands of bushels of grain, mostly wheat, were being shipped south from Minnesota to St. Louis and points further south. River traffic began to decrease in the 1860s when railroads began to cross the Mississippi River including construction of bridges at Quincy and Hannibal.

As early as the 1830s, snags and other local obstructions such as shoals, sandbars, and rocks were removed from the main-stem Mississippi River to ensure a safe passage for steamboats (Upper Mississippi River Basin Commission 1981). As steamboat traffic increased and competition from railroads increased Congress made 16 appropriations for river and harbor projects in the UMRS between 1866 and 1883 (Hoops 1993). These projects were intended to improve the Mississippi River's efficiency for commercial navigation and they stimulated many future attempts to improve the system for navigation (Brunet 1977, Anfinson 1993). In 1878, Congress authorized the USACE to develop and maintain a 4.5-foot deep navigation channel between St. Paul and St. Louis. To divert river flows into the main channel, wing dams were constructed perpendicular to the riverbanks. Side channels were cut off with closing dams and many riverbanks were stabilized by revetments.

In 1907, Congress authorized a deeper 6-foot channel and subsequent river modifications consisted of further river contraction and bank protection and the construction of the first lock and dam at Keokuk, Iowa in 1913 which had both navigation and hydropower purposes (Theiling 1999). In 1927, Congress authorized the development of a navigation channel of 9 feet deep and 300 feet wide from the mouth of the Missouri and Mississippi rivers near St. Louis to the mouth of the Ohio River at Cairo, Illinois. This 9-foot channel project resulted in more extensive flow constriction and more bank stabilization structures, but no construction of locks and dams in the region. In 1930, the 9-foot channel was extended north from St. Louis to St. Paul and during the 1930s, a series of 27 locks and dams were constructed (Table 6). Each dam was intended to impound water during low river flows to maintain a minimum 9 foot navigation channel.

Landscape changes in the Cannon-Great River region prior to construction of locks and dams are identified by data from the GLO surveys, maps of the Mississippi River floodplain prepared by the Mississippi River Commission in the 1880s (see examples in Heitmeyer and Bartletti 2012), old aerial photographs from the 1940s (example in Fig. 15), and maps prepared by Brown in 1930 (Brown 1931). Collectively, these maps and photographs show the relatively rapid: 1) conversion of bottomland prairies and oak savannas to agriculture and residential/urban communities; 2) clearing of floodplain forest, especially on higher elevation ridges, natural levees, and terrace edges, for agriculture and some urban uses; 3) clearing of slope forest for agriculture and pasture; and 4) marked changes in other floodplain areas including conversion to agriculture, levees and drainage developments, alterations in sloughs, side channels, and the main stem Mississippi River.

As an example of the intense and quick conversion of native habitats in the Cannon-Great Rivers NWR region, the majority of what is now Cannon NWR was drained, ditched, leveed, and cleared for agricultural production from about 1920-30 (USACE 2013). In the 1920s, parts of the former bottomland prairie landscape at Cannon were leveled to grow rice. Additionally, drainage ditches were built and levees were constructed that constricted the floodplain and isolated the area from the Mississippi River and Bryants and Ramsey creeks. By 1929, interior berms and drainage channels were built to divide the area into individual rectangular agricultural parcels. U.S. War Department maps from 1929-30 showed the Cannon area divided into two levee and drainage districts with an agricultural berm surrounding the entire area. Collectively, by the 1930s, about 50% of Presettlement natural communities, and over 80% of historic prairie and savanna, had been lost in the UMRS. By 1929 farmland and urban areas covered 22% of the UMRS floodplain and forest had declined to 29% of its former extent (Peck and Smart 1986). Specifically, the Pool 25 area contained 46% wet prairie, 35% floodplain forest, 18% open water, and <1% marsh in the early 1800s but by 1989 it contained 54% agriculture, 19% floodplain forest, 6% wet prairie, and <1% marsh (Table 7, Theiling et al. 2000).

POST LOCK-AND-DAM HYDROLOGICAL AND LANDSCAPE CHANGES

Locks and Dams on the Mississippi River in the UMRS were constructed between 1935 and 1939 (WEST Consultants, Inc. 2000). Locks 20 and 24 were constructed first in 1936, followed by Lock 21 and the original Lock 26 in 1938, and then Lock 25 in 1939 (Table 8). These locks-and-dams created pool lengths of 18.3 to 38.5 miles. The immediate effect of the locks and dams was significant change in hydrographs of the Mississippi River and its floodplain communities and impoundment of lower parts

Table 6. Interpolation of return intervals (e.g. 100 means a 1% likelihood) for Mississippi River flows and water surface elevation for river miles adjacent to Clarence Cannon NWR, Fox Island Division and Long Island Division of Great River NWR. Discharge in cubic feet per second (from Newman 2012).

Return Interval	Discharge (cfs)	Elevation (NGVD 1929)
2	210,000	442.6
5	269,000	445.8
10	310,000	447.5
25	370,000	449.8
50	404,000	450.7
100	443,000	451.7
200	489,000	452.7

Peak elevation and discharge for the Mississippi River (Mile 262) near Clarence Cannon NWR.

Return Interval	Discharge (cfs)	Elevation (NGVD 1929)
2	200,000	488.0
5	245,000	490.9
10	282,000	492.6
25	317,000	494.3
50	353,000	495.8
100	396,000	497.4
200	442,000	498.8

Peak elevation and discharge for the Mississippi River (Mile 356) near Fox Island Division.

Return Interval	Discharge (cfs) Mile 340	Elevation (NGVD 1929)-Mile 340	Discharge (cfs) Mile 333	Elevation (NGVD 1929)-Mile 333
2	203,000	481.2	204,000	477.5
5	255,000	484.1	255,000	480.3
10	286,000	485.5	288,000	482.2
25	326,000	487.5	333,000	484.8
50	364,000	489	375,000	486.7
100	408,000	490.5	419,000	488.4
200	454,000	491.9	463,000	489.8

Peak elevation and discharge for the Mississippi River (Mile 340 and 333) at the upstream and downstream ends of Long Island Division

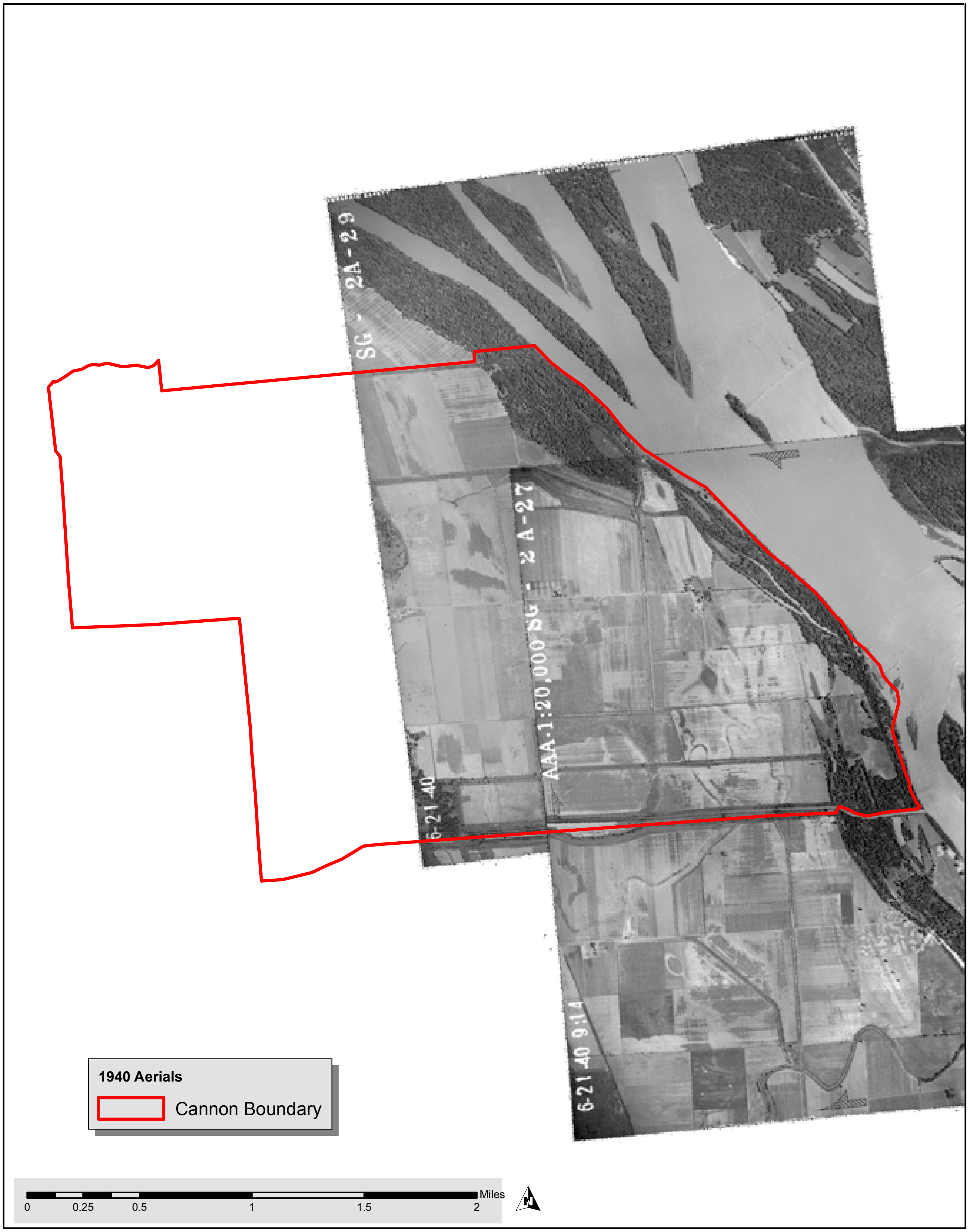


Figure 15. 1940 aerial photograph of the area now in Clarence Cannon NWR. Images not available for western part of the refuge.

of each pool. The pre-dam era was characterized by an average pattern of high river stage during snowmelt and spring rains that tapered to summer low flow river stages, rose with fall rains, and froze at a moderate river stage in winter. Navigation dams increased average water surface elevations by about two to three feet and eliminated natural low-flow river stages during late summer (Theiling 1996). The post-dam change in water surface profiles for the discharge exceeded 75% of the time (i.e., low flow conditions) is especially marked (Fig. 8). Stage-discharge relationships also have changed in all navigation pools in the Cannon-Great River reach with headwater (immediately above the dam in the impounded section of the pool) differences being 6 to 12 feet higher for existing vs. pre-dam low flow conditions (West Consultants, Inc. 2000, Heitmeyer 2010). In contrast, tailwater areas immediately downstream of dams have stage-discharge relationships that indicate water surface elevations up to one to two feet higher for low flow conditions and up to two feet lower for high flow conditions depending on the dam.

Table 7. Percentage composition of major landcover types in Pools 22, 24, and 25/26 in the early 1800s Presettlement and 1989 periods (from Theiling et al. 2000).

	Pool 22		Pool 24		Pools 25/26	
Habitat type	P[a]	C	P	C	P	C
Prairie	35	4	47	3	47	6
Forest[b]	52	12	40	13	35	19
Open water	13	10	13	10	18	18
Developed	-	2	-	1	-	3
Agriculture	-	72	-	72	-	53

[a] P – Presettlement, C – 1989.

[b] Combined Riverfront, Floodplain, and Slope Forest types (see text).

Table 8. Summary of locks, dams, and pools along the Mississippi River in the Cannon-Great River NWR region (from WEST Consultants, Inc. 2000).

Lock name or number	River mile	Pool length (mi.)	Drainage area (sq. mi.)	Began operation
20	343.2	21.0	134,300	1936
21	324.9	18.3	135,200	1938
24	273.4	27.8	140,900	1936
25	241.4	32.0	142,000	1939

River systemization following construction of locks and dams did not change seasonal patterns of Mississippi River flows in the Cannon-Great River region, but decreased the range between low and high average flows and also compressed long-term patterns of dry vs. wet cycles (e.g., Franklin et al. 2003). For example, at Hannibal, low flow periods now are decreased to 2-3 year duration compared to 4-5 year duration prior to construction and operation of Lock and Dam 24, while high flow periods have remained at about 4-5 year duration (Franklin et al. 2003). In addition to the construction of locks-and-dams, large mainstem levees were constructed along the Mississippi River beginning in the early 1900s and by 1990 about 70% of floodplains in Pools 22, 24, and 25 were leveed; most of the remainder was along large bluffs where no levee was needed. Floodplain stratigraphy in the last two centuries generally indicates that accelerated runoff in the Upper Mississippi River Valley is associated with continued conversion of native habitats to agricultural production, changes in ongoing agricultural crop practices, and that magnitude of floods in the system and in the Cannon-Great River region has increased (Knox 1993, 1996, 2001).

Mississippi River Commission maps in the UMRS compared to current river morphology and navigation pool area provide a basis for comparing changes in river morphology over time. In general, by 1891, the Pool 24 area had more islands, was narrower, and had more sand transport than in the early 1800s (Heitmeyer 2008a). Further, by 1891, more than 40 miles of levees extended along the Upper Mississippi River bank in the pool region; the largest and longest levee was the Sny Levee built along the Illinois side of the Mississippi River from RM 264 to RM301 (Petterchak 2002). This Sny Island Levee Drainage District is the oldest drainage district in Illinois, officially established in 1880 (Olson et al. 2011). Shortly after the district was formed, the large Sny Levee was constructed along the Mississippi River and this levee effectively disconnected the Sny River corridor and adjacent floodplains from the Mississippi River and deflected sediments and flood flows

Table 9. Average riverbed elevations (feet above mean sea level) in the Pool 24 stretch of the Mississippi River, 1891 - 1971 (calculated from Simons et al. 1975).

	Riverbed elevation			
Location	1891	1929	1939	1971
Lower quarter	425.5	426.8	424.7	427.4
Middle half	430.7	430.5	427.2	429.2
Upper quarter	435.1	436.6	430.8	432.7

onto the Missouri side of the river. Construction of locks and dams in and upstream of Cannon and Great River NWRs essentially stopped normal movement of sediments into and through the region and average riverbed elevations aggraded by about two feet (Table 9). Water and sediment flows into the Pool 24 and downriver regions also now are affected by Mark Twain Reservoir, built on the Salt River in Missouri in the late 1970s. Water management on Mark Twain Reservoir has eliminated most overbank flooding on the Salt River below the reservoir dam and has changed seasonal patterns of high and low flows in this river system (Heitmeyer 2008a).

The UMRS is a major source of nutrients (especially nitrate) that contribute to hypoxia problems in the Gulf Coast (Davinroy 2006, Rabalais et al. 2002). Nutrients and sediments that affect Cannon-Great Rivers NWRs come from many sources including the Mississippi River and its tributaries, regional ditches and tile drainage systems, and groundwater (Herman 2010). Aquatic life in river and backwaters on refuges are exposed to many metals, fecal coliform, organic chemicals, and other contaminants. Contaminant assessments on the refuge divisions has detected slightly elevated concentrations of heavy metals (such as manganese and iron on the Fox River Division, USACE 2008), but little organic pollutions from DDT, chlordane, or PCB (Herman 2010). Sedimentation is a major concern for all refuge areas, especially at Long and Fox Islands where river chutes and channels are deposition sites for sediment in Mississippi River waters that originates from upstream erosion of mainly farm lands. Construction of Lock and Dams 20-25 collectively have slowed river velocities and increased sediment deposition, especially in areas immediately upstream of the dams (USFWS 2012). Conversely, Long Island is immediately downstream of Lock and Dam 20, which suggests that upstream areas on the Division may be experiencing erosion and stream down-cutting because of reduced sediment importation from Pool 20.

The northern boundary of Cannon is Ramsey Creek and Bryants Creek forms the southern boundary of the refuge. These creeks drain primarily agricultural lands and also are subject to backwater flooding from the Mississippi River. Water is pumped from Bryants Creek into Cannon for wetland management. Both creeks currently are assessed as "good" for a designated use of "protection of aquatic life such as the warm water fishery (Missouri Department of Natural Resources 2010).

Land use in the Cannon-Great River region continued to change from the late 1890 to the present. By 1989, Pre-settlement habitats in the region had shifted to greater amounts of developed land and agriculture and lesser amounts of forest and prairie/savanna (Table 7). Much of the forest in areas to be impounded by the navigation pools was conducted by the USACE prior to closure of the lock and dams. Thereafter, remaining areas in the lower sections of the pools became essentially permanently inundated and caused mortality of remaining trees in those areas (Green 1947, Yeager 1949, Yin and Nelson 1996, Nelson and Sparks 1998, Knutson and Klaas 1998, Yin 1998, 1999, Covington and Laubhan 2005). Loss of remaining forest area (of all types) in the Cannon-Great River region was often latent from the time of construction of locks-and-dams, with eventual mortality and conversion of forest habitats to more water tolerant plant communities such as S/S, perennial marsh, and open water occurring as late as the present time.

The large floods on the Mississippi River in 1993, 1995, and 2008 further exacerbated the collapse of many forest areas, especially those BLH, oak-savanna, and floodplain forest sites that historically contained larger amounts of the hard mast oaks and pecan (e.g., Heitmeyer 2008b). Declines in all forest types have occurred, with remnant forest sites now confined to the higher elevations where historic forest communities were present (USFWS 1944). Obviously, impoundment post-dam in lower portions of the navigation pools quickly killed all forest present. Forest mortality in middle and upper parts of pools has been more delayed, yet the latent persistent higher levels of surface water inundation and soil saturation have prevented regeneration of floodplain forest seedlings for most species and gradually weakened, and eventually killed, large areas of green ash, American elm, box elder, swamp white oak, and hackberry. Significant loss of floodplain forest, especially remnant elm and ash has occurred even in the last 10 years. Floodplain forest species are adapted to seasonal flooding in the UMRS, but they need drying periods in summer and fall to maintain root systems and allow regeneration of seedlings. Further, long-term sustainability of these species requires periodic periods of extended drying, that historically occurred for 2-4 consecutive years during dry periods of long-term climatic (see also discussion in Heitmeyer 2010).

Remnant areas of riverfront forest have been impacted less than floodplain forest because they contain silver maple, willow, and cottonwood, which have greater water tolerance. Nonetheless, species diversity in riverfront forest areas has been reduced and is quickly becoming more monocultures of silver maple and willow (e.g., Fig. 16, Nelson and Sparks 1998). Most of the dead and/or dying forest area has converted to S/S, PEM, wet meadow, or open water habitats (Yeager 1949, Nelson and Sparks 1998, Heitmeyer 2008a).

Combined timber harvest (largely prior to locks and dams), water level regulation, bank stabilization structures, dredging, island erosion, sedimentation and expansion of invasive and exotic plant and animal species have collectively greatly altered the historic community distribution, extent, and composition in the Cannon-Great River region (e.g., U.S. Geological Survey 1999, Theiling et al. 2000, WEST Consultants, Inc. 2000). The cumulative impacts of alterations to the Mississippi River system, especially since implementation of measures to maintain a 9-foot navigation channel, including construction of locks and dams, is extensively documented (WEST Consultants, Inc. 2000).

Currently, several exotic and invasive plant and animal species are present on Cannon and Great River NWRs (USFWS 2004, 2012). Reed canary grass (RCG) is a persistent problem on all divisions. RCG expanded throughout the UMRS after the 1993 flood, which provided an avenue for wide disbursement of RCG seeds. Other common problem species include Canada thistle, Japanese stilt grass, garlic mustard, bush honeysuckle, river bulrush, swamp smartweed, honey locust, and grey dogwood.

ESTABLISHMENT, DEVELOPMENT, AND MANAGEMENT OF CANNON AND GREAT RIVER NWRS

Fox Island

The Fox Island Division was created in 1989 when 1,037 acres adjacent to Pool 20 were purchased by the USFWS. In response to habitat degradation and loss along the Mississippi River following the 1993 flood, an additional 1072 acres were purchased and added to the Division in 1996 and 1997. A portion of the west boundary of Fox Island touches the Rose Pond Conservation Area owned and managed by the Missouri Department of Conservation. Most of the Division is unleveed and subject to regular flooding, especially in spring and early summer, from the Fox and Mississippi rivers. A levee on the west side of the area constrains Mississippi and Fox River flood waters from covering adjacent private farm land and a small upland area on the west side of the Division (Figs. 17a, 18a). Higher ground on Fox Island historically was farmed, but all farming was discontinued on the division in 2010. Limited wetland developments historically occurred on the area because of its proximity to the river and frequent floods, porous soils, and the many connected sloughs, chutes, and side channels. In the 1990s, three sloughs covering about 130 acres that contained old agricultural drain ditches were blocked with water-control structures to restore water regimes in the sites. Specifically, the USFWS excavated and cleared channels in and around Coin Pond and Logsdon Slough to promote connectivity between the wetlands and installed galvanized metal stoplog structures to increase water management capability (Fig. 19a). These wetland areas are flooded by natural runoff or flooding and typically are dry during fall and winter.

In 1998, the USACE prepared a Habitat Restoration and Enhancement Program (HREP) project for Fox Island (USACE 1998). This HREP project currently is under final development and includes planting mast-producing trees (mainly oak) on 215 acres of former farm land using container-grown stock and direct seeding acorns and pecan on an additional 60 acres (Fig. 20). Other HREP developments including installing two groundwater wells, improving water

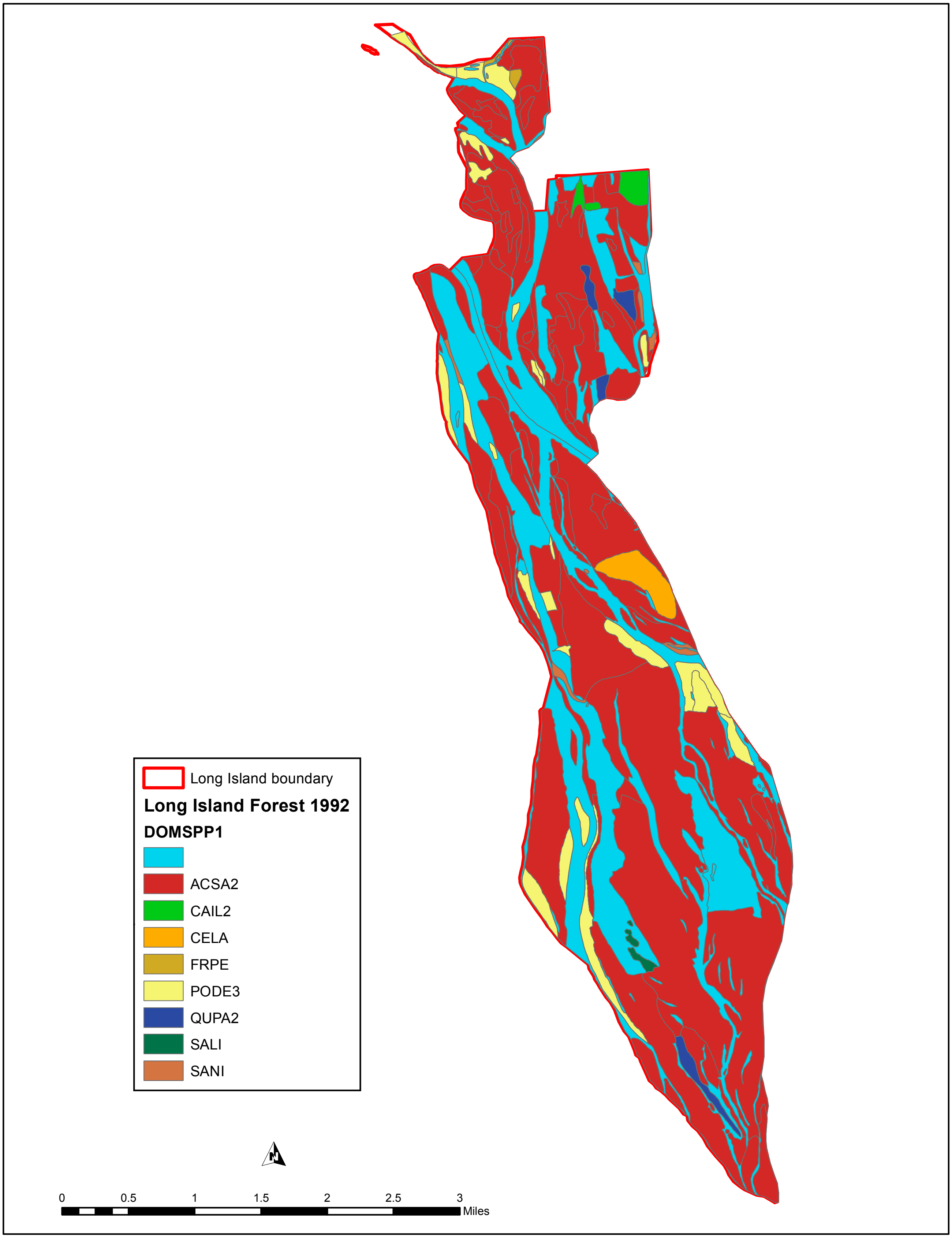


Figure 16. Forest inventory maps for Long Island NWR in 1992. ACSA – silver maple, CAIL – pecan, CELA – sugarberry, FRPE – green ash, PODE – cottonwood, “QUPA – pin oak, SALI and SANI – willow.

distribution and supply channels, and placing water-control structures in and around Logsdon Slough, Coin Pond, Slim Slough, and Old Lake.

Long Island

The first property to become part of the Cannon-Great River NWR complex was the Long Island Division, added in 1958. Long Island was acquired by the USACE following construction and establishment of Pools 20 and 21 in the 1930s, and it eventually became part of the NWR system through Mississippi River GP Agreement. The division contains about 6,700 acres of river chutes and side channels, islands, and floodplain (Figs. 17a, 18a). Major islands on the division are Barnes, Shandrew, Flannigan, Long, and LaGrange. Floodplain lands on the Division are directly connected to, and subject to flooding from, the Mississippi River (Fig. 19b). In the early 1970s, six small moist-soil units were constructed in the south-central portion of the area along Long Island Lake. The units were contained by low-level dikes and natural ridges and totaled about 40 acres. Screw-gates and flash-board riser water-control structures were installed to enable water management, however, subsequent regular flooding damaged levees and sedimentation occurred behind structures, which eventually disabled the units and they no longer are functional or managed.

Long Island contains about 4,670 acres of forest that currently is dominated by early succession riverfront forest, mainly silver maple and willow (Fig. 16). A few higher elevation areas contain pecan, sugarberry, green ash, and pin oak. Forest land on Long Island is the largest contiguous area of forest along the Mississippi River floodplain from Rock Island to Cairo, IL. Forest management on the division remains under the control of the USACE and some timber stand improvement and harvest has occurred in the past (USACE 2012).

The large Mississippi River flood in 1993 caused extended flooding of Long Island throughout summer and extensive tree mortality occurred in subsequent years. Most mortality, unfortunately, was tree species that occupied higher elevations and that were not as tolerant to extended growing season flooding such as pin oak, pecan, sugarberry, elm, and ash. Starting in the 1990s, cleared areas on the division that previously had been farmed were retired and restored to forest under cooperative agreement with the USACE. The 124-acre Bear Creek agricultural unit was abandoned following the 1993 flood and the last 160 acres of farmland on the division currently is being converted to forest.

Sedimentation in river chutes and side channels has greatly reduced depth and clarity of these waters and boat travel in limited in these areas. Sedimentation has reduced fish habitat and abundance in these chutes and side channels (USACE 2012). The USACE partly dredged some areas and closed one side chute to reduce sedimentation and create deeper water fish habitat.

Delair

The Delair Division was purchased by the USFWS in 1965 and 1976. It is entirely within the Sny Agricultural Levee District and is separated from the Mississippi River by the mainline Sny Levee. The sandy soils in the levee and floodplain allow seepage of Mississippi River water into some low elevation areas of the area, especially the Cattail Marsh area. When the USFWS acquired Delair, it was mostly agricultural fields except for the Swan Lake wetland complex and other low elevation wetland seep areas. Currently, about 400 acres of the area are farmed annually through cooperative agreements with local farmers. Ten water-control structures are present on Delair along with several internal ditches (Fig. 19c). Management of the area is within 19 distinct units (Fig. 6), which contain a complex of woody wetlands, PEM, moist-soil, and agricultural lands (Figs. 17b, 18b).

Historically, management of Delair has sought to maintain about 480 acres of semipermanently and permanently flooded wetland areas, mainly in the Upper and Lower Swan Lake sites, which are old natural wetland depressions in the floodplain. Other primary wetland management areas include the Cattail Marsh complex, Lower Butcher Marsh, Shoveler Marsh, and the Hanei marsh areas (Fig. 6). In these areas, water level manipulation, mowing, and disking have been used regularly to promote diverse wetland vegetation habitats and moist-soil type foods. About 400 acres of Delair have been farmed annually on higher elevation ridges and in some wetland management units where farming is used in a rotation to promote moist-soil plants, deter invasive species, and control woody vegetation.

Delair historically contained areas of floodplain and bottomland forest, but these areas were largely cleared for agricultural production in the mid 1900s. Remnant patches of forest exist on the area, and some forest sites have experienced mortality from seepage

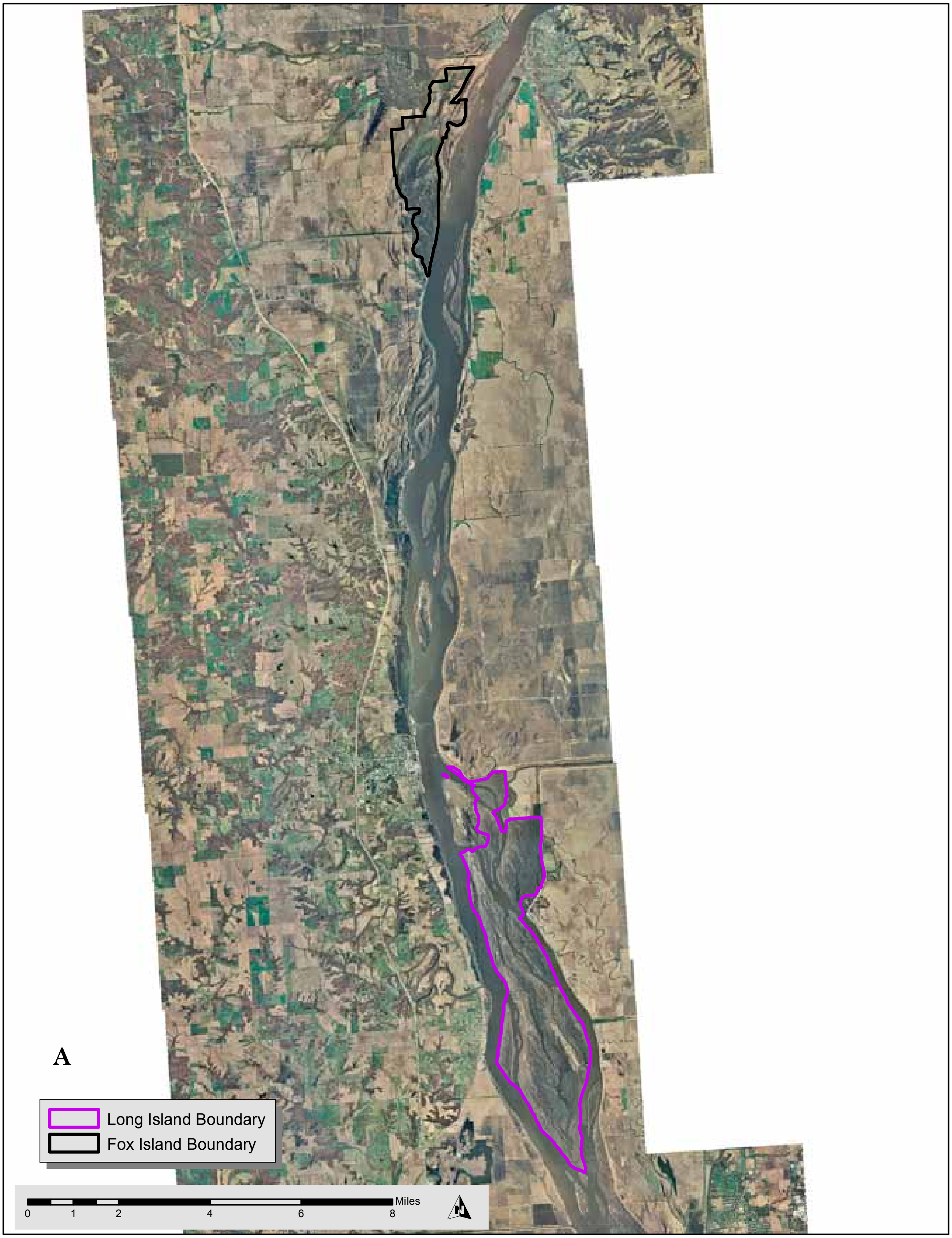


Figure 17, continued. 2010 NAIP aerial photographs of: a) Long and Fox Island units of Great River NWR, b) Delair unit of Great River NWR, and c) Clarence Cannon NWR (from USGS DataGateway).

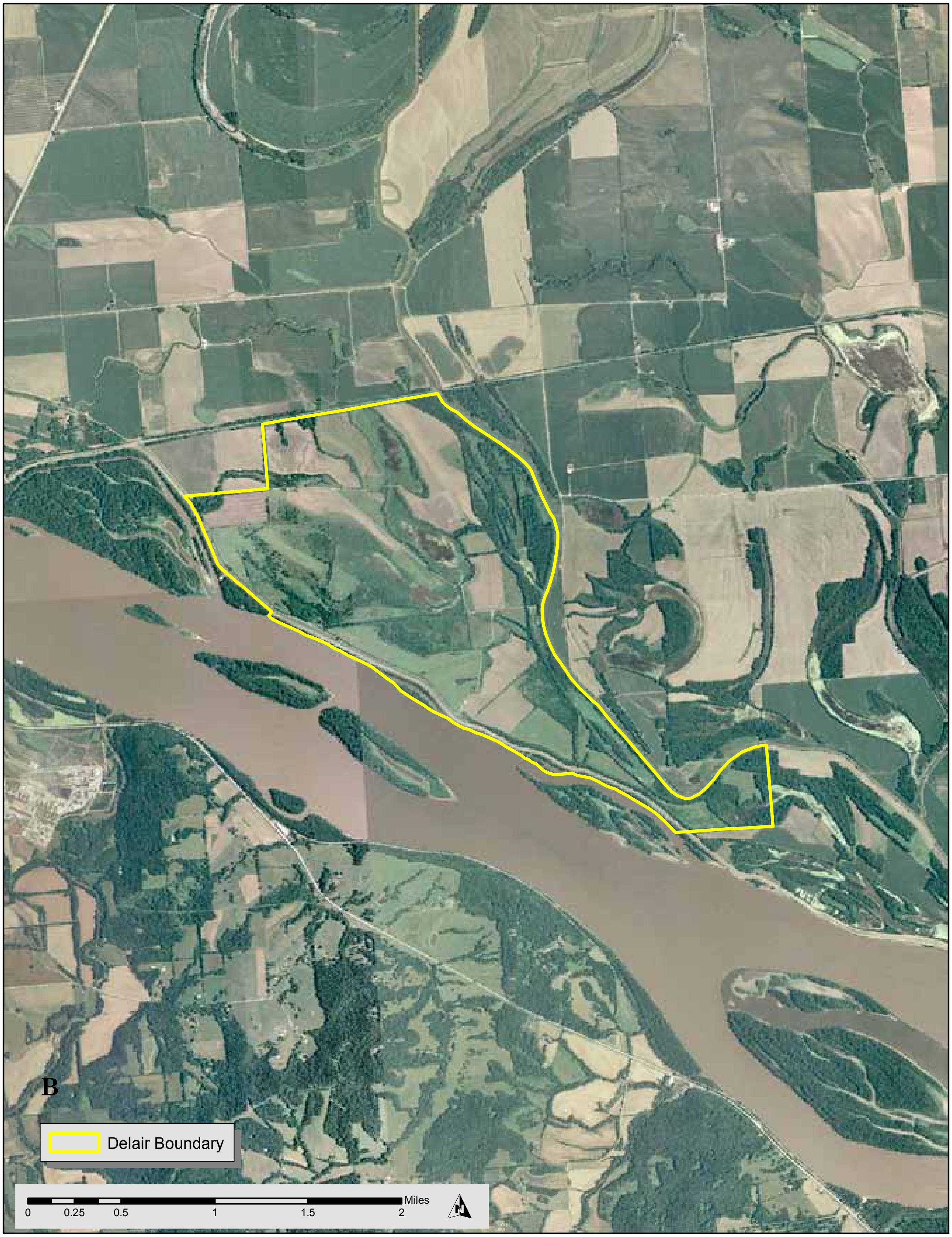


Figure 17, continued. 2010 NAIP aerial photographs of: a) Long and Fox Island units of Great River NWR, b) Delair unit of Great River NWR, and c) Clarence Cannon NWR (from USGS DataGateway).

Figure 17, continued. 2010 NAIP aerial photographs of: a) Long and Fox Island units of Great River NWR, b) Delair unit of Great River NWR, and c) Clarence Cannon NWR (from USGS DataGateway).

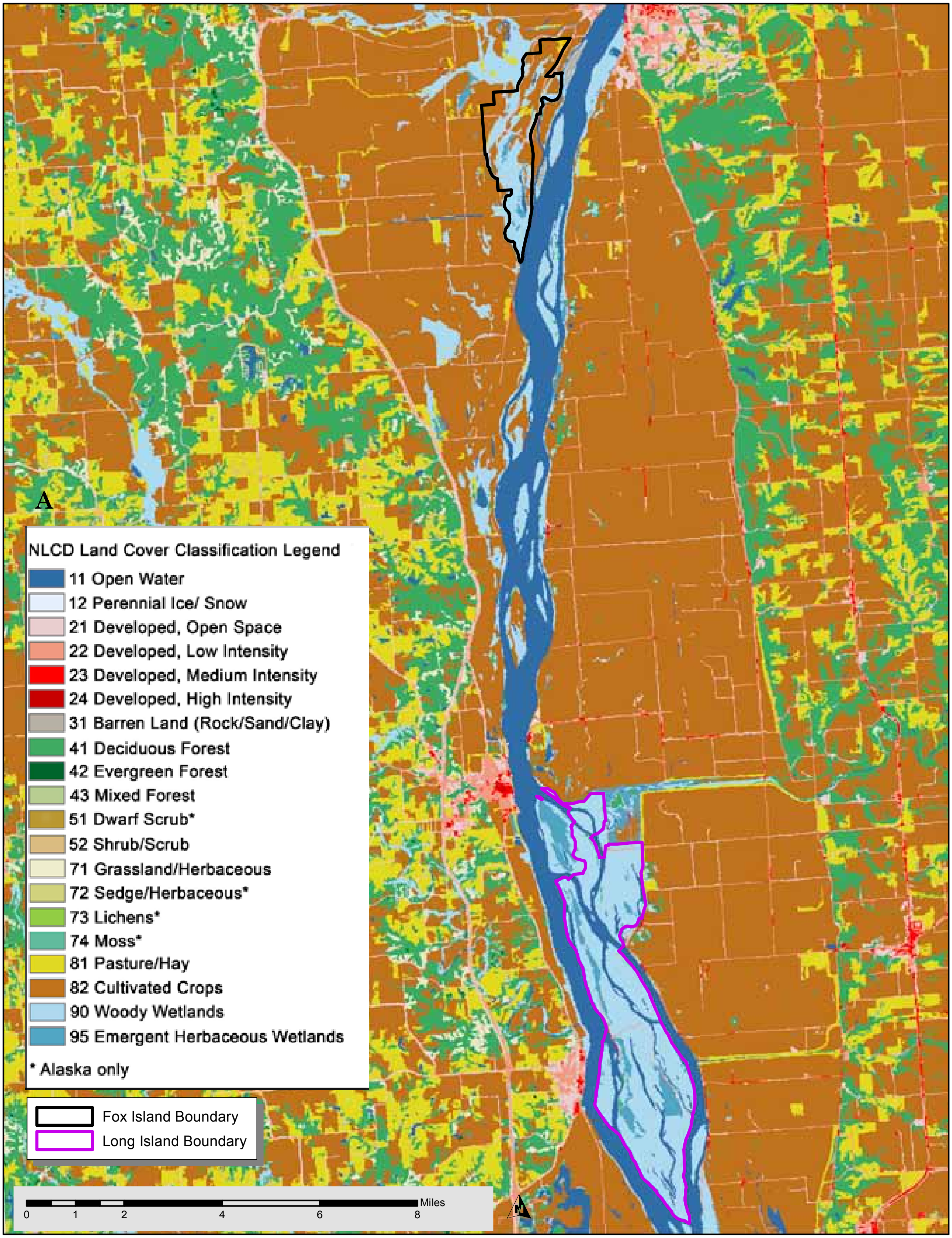


Figure 18. National land cover data maps from 2000 for: a) Long and Fox Island units of Great River NWR, b) Delair unit of Great River NWR, and c) Clarence Cannon NWR (NLCD data provided by USFWS).

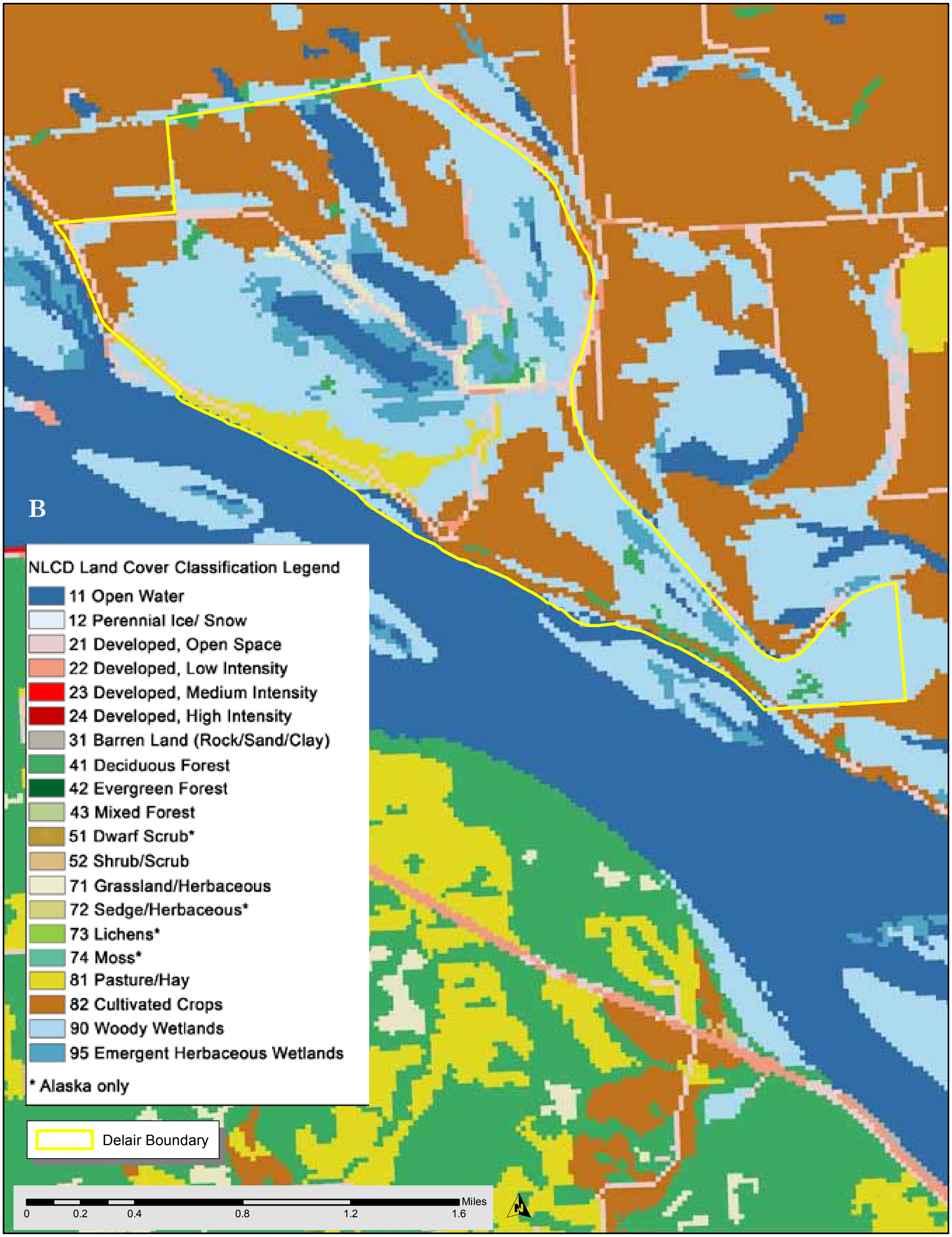


Figure 18, continued. National land cover data maps from 2000 for: a) Long and Fox Island units of Great River NWR, b) Delair unit of Great River NWR, and c) Clarence Cannon NWR (NLCD data provided by USFWS).

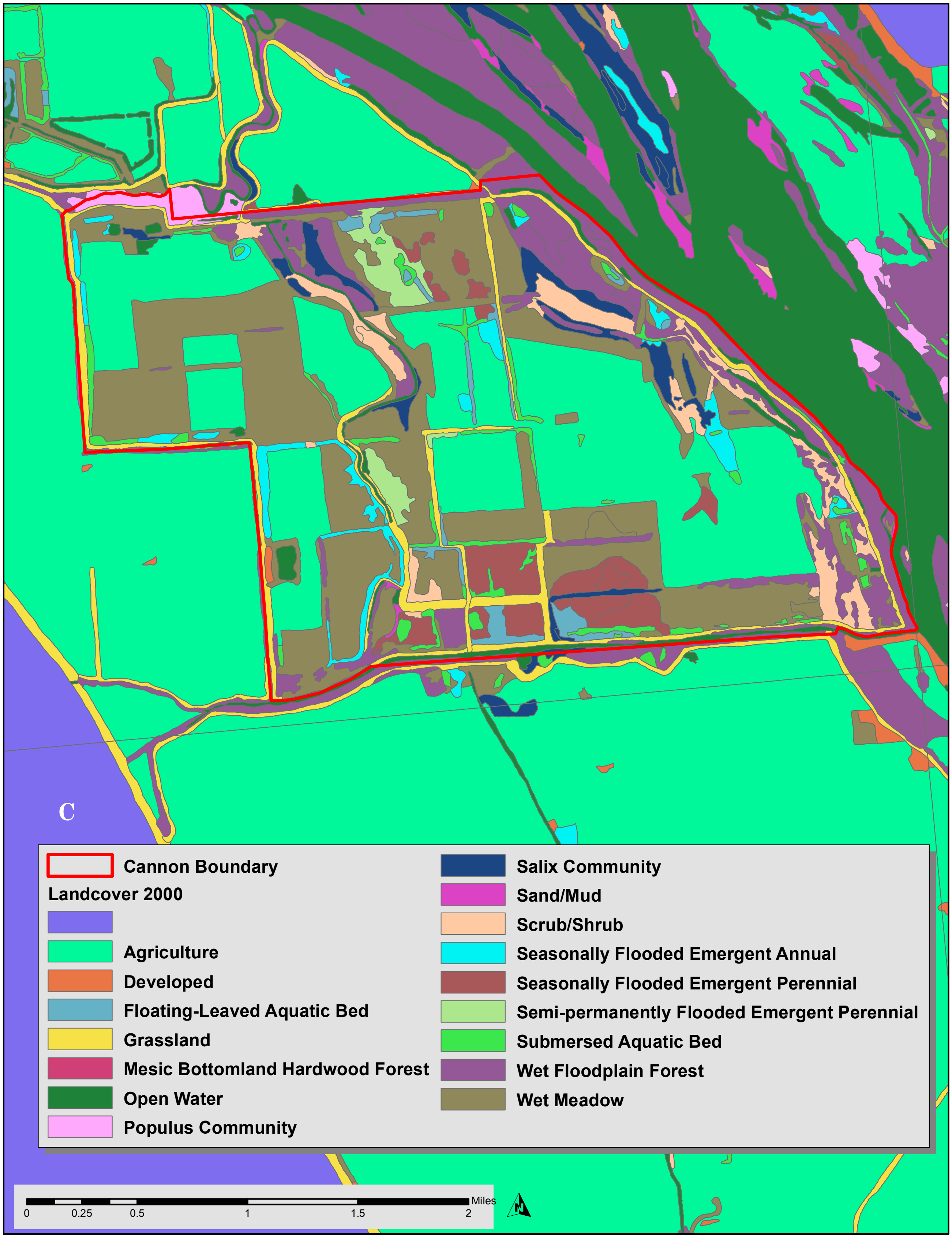
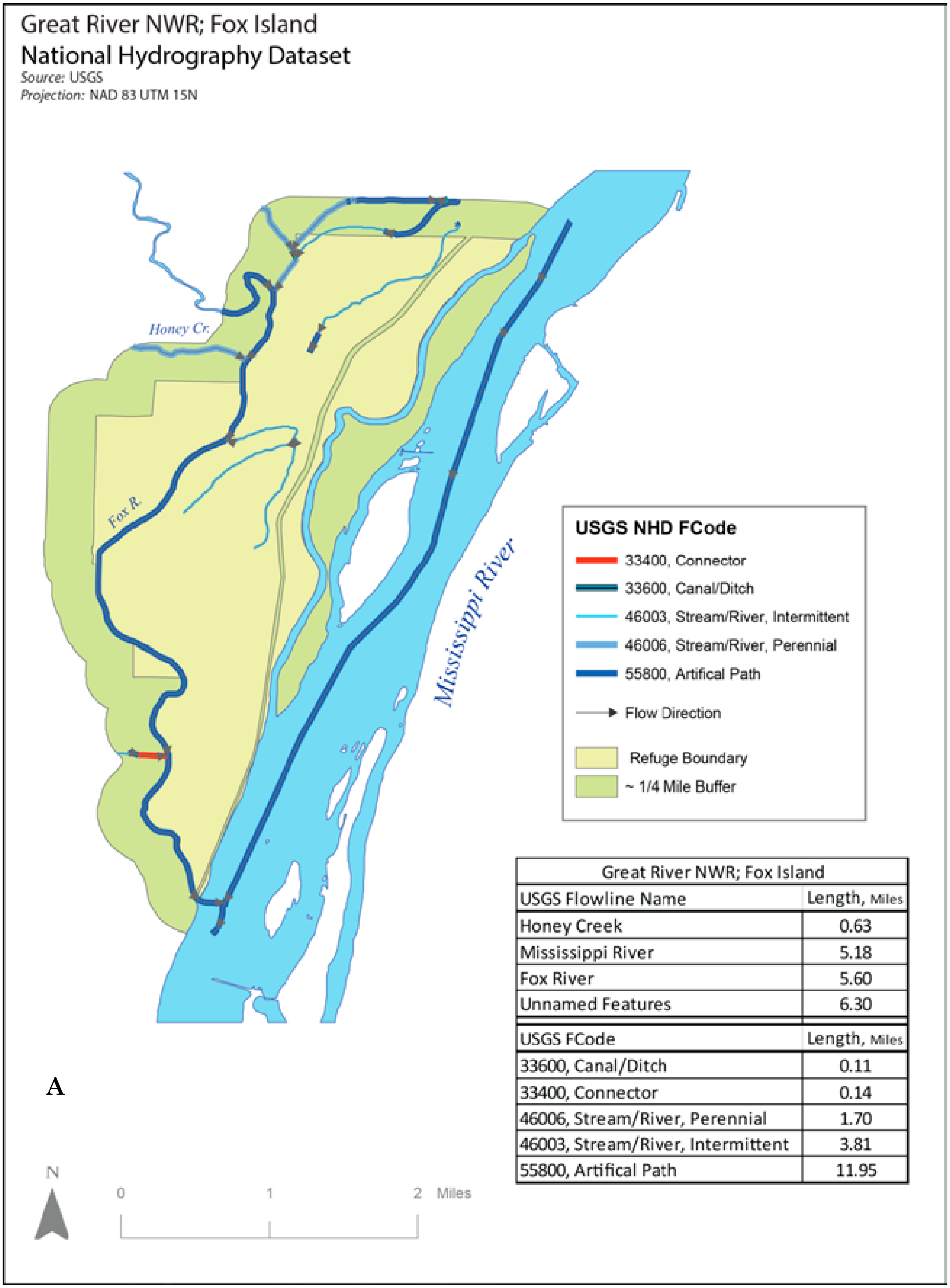
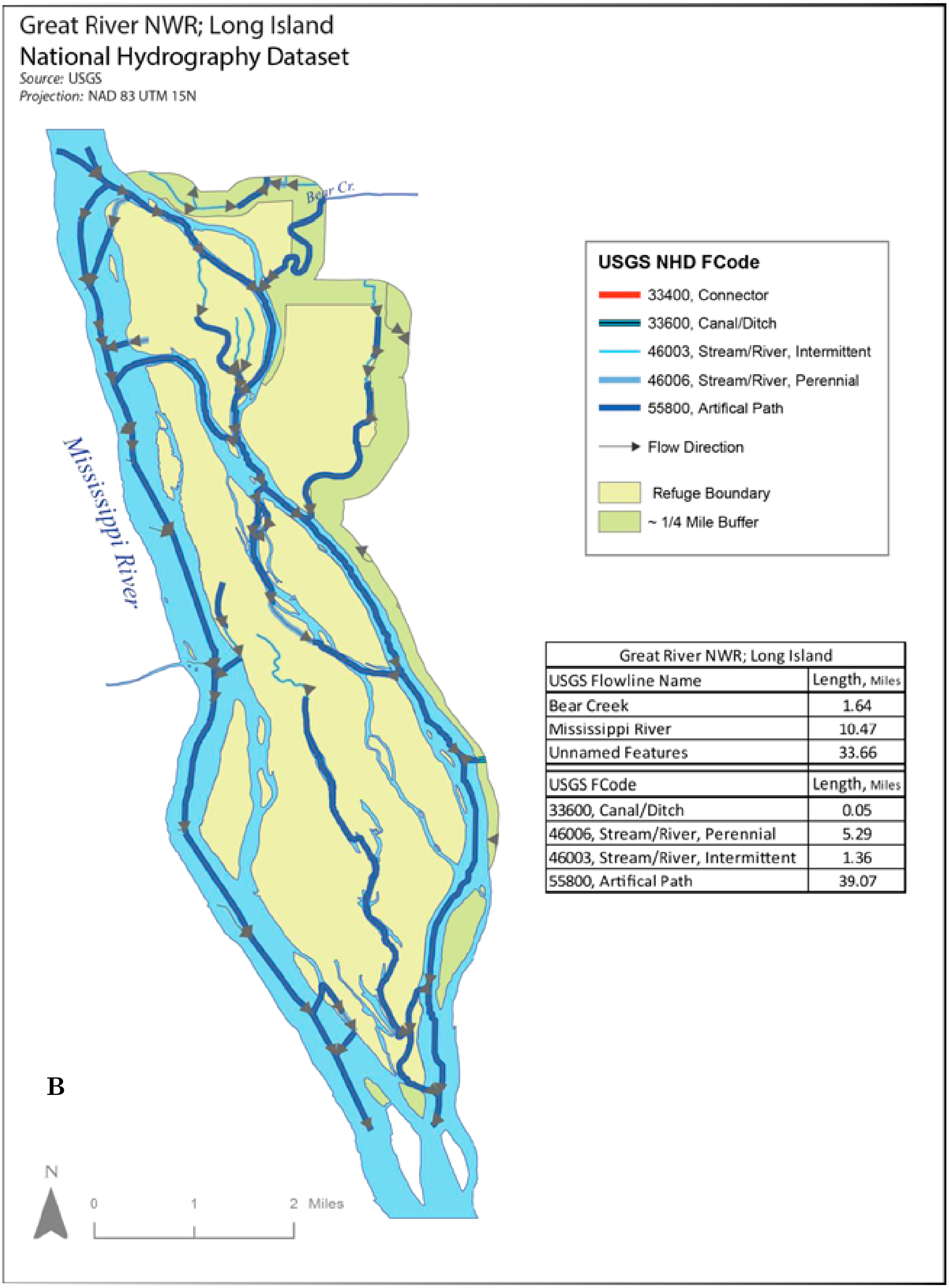


Figure 18, continued. National land cover data maps from 2000 for: a) Long and Fox Island units of Great River NWR, b) Delair unit of Great River NWR, and c) Clarence Cannon NWR (NLCD data provided by USFWS).



Great River NWR; Fox Island	
USGS Flowline Name	Length, Miles
Honey Creek	0.63
Mississippi River	5.18
Fox River	5.60
Unnamed Features	6.30
USGS FCode	Length, Miles
33600, Canal/Ditch	0.11
33400, Connector	0.14
46006, Stream/River, Perennial	1.70
46003, Stream/River, Intermittent	3.81
55800, Artifical Path	11.95

Figure 19. Water flow and water management infrastructure for Great River NWR: a) Fox Island unit, b) Long Island unit, c) Delair unit; and d-e) Clarence Cannon NWR (from Newman 2012).



Great River NWR; Long Island	
USGS Flowline Name	Length, Miles
Bear Creek	1.64
Mississippi River	10.47
Unnamed Features	33.66
USGS FCode	Length, Miles
33600, Canal/Ditch	0.05
46006, Stream/River, Perennial	5.29
46003, Stream/River, Intermittent	1.36
55800, Artifical Path	39.07

Figure 19, continued. Water flow and water management infrastructure for Great River NWR: a) Fox Island unit, b) Long Island unit, c) Delair unit; and d-e) Clarence Cannon NWR (from Newman 2012).

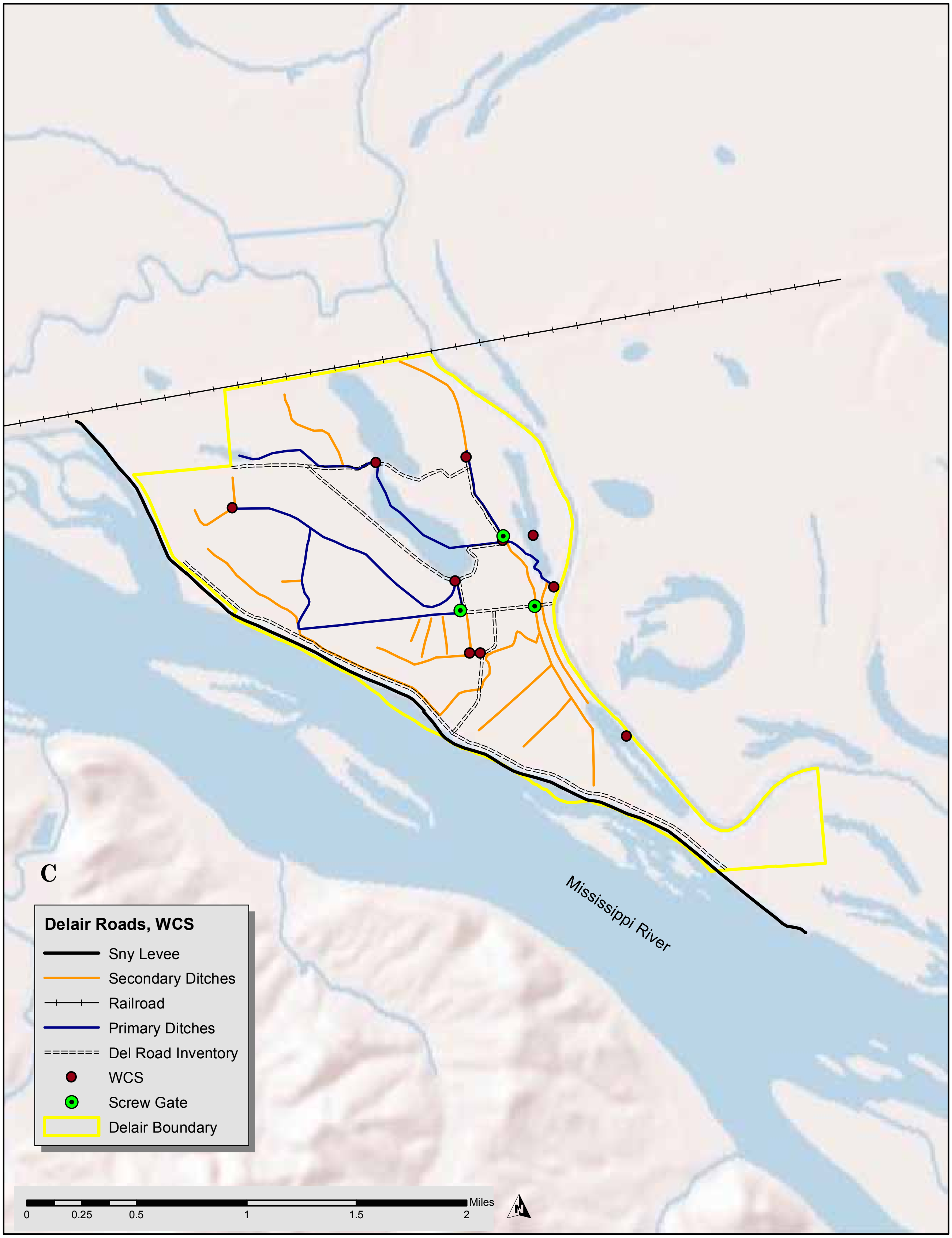


Figure 19, continued. Water flow and water management infrastructure for Great River NWR: a) Fox Island unit, b) Long Island unit, c) Delair unit; and d-e) Clarence Cannon NWR (from Newman 2012).

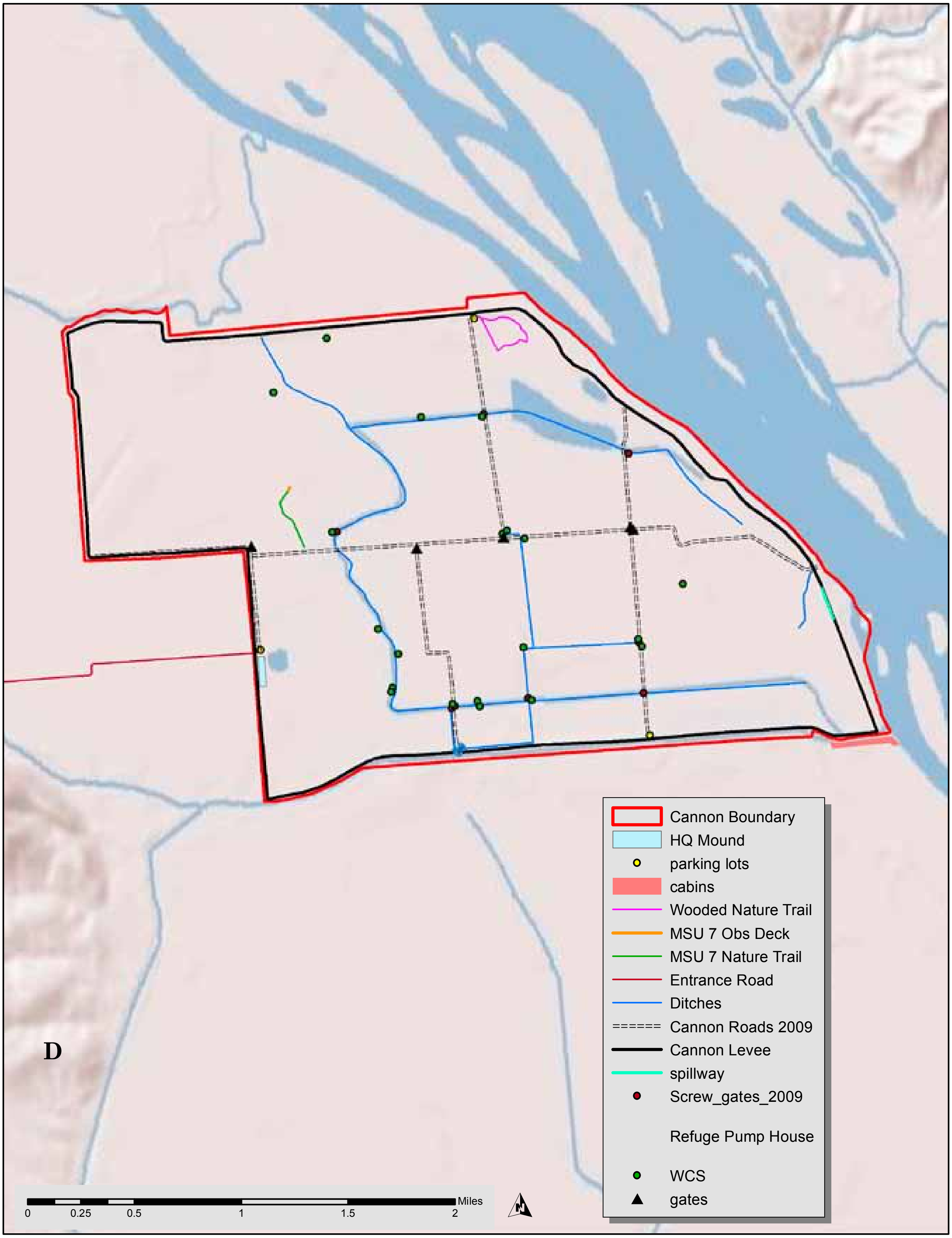
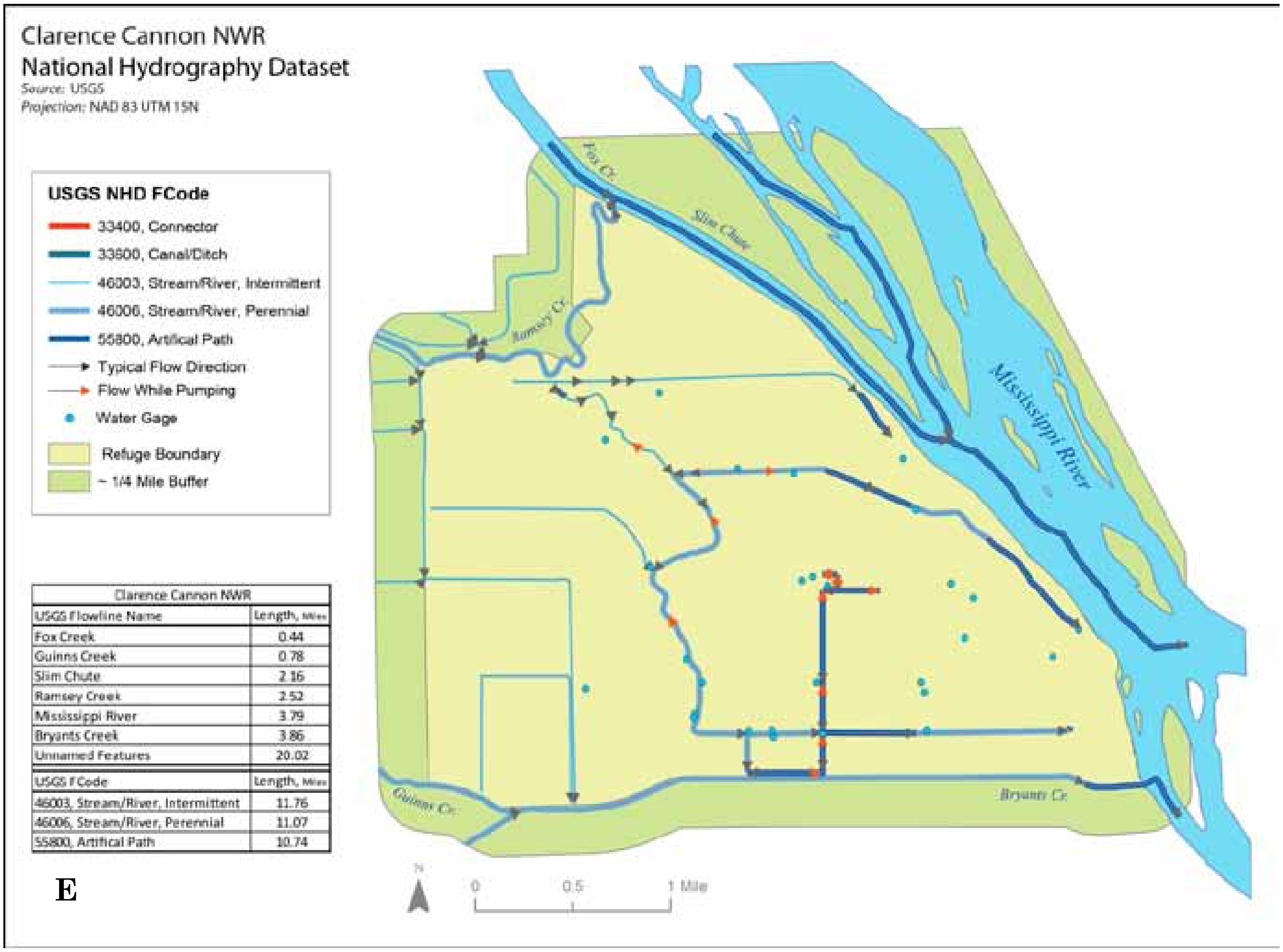


Figure 19, continued. Water flow and water management infrastructure for Great River NWR: a) Fox Island unit, b) Long Island unit, c) Delair unit; and d-e) Clarence Cannon NWR (from Newman 2012).



Clarence Cannon NWR	
USGS Flowline Name	Length, Miles
Fox Creek	0.44
Guinns Creek	0.78
Slim Chute	2.16
Ramsey Creek	2.52
Mississippi River	3.79
Bryants Creek	3.86
Unnamed Features	20.02
USGS FCode	Length, Miles
46003, Stream/River, Intermittent	11.76
46006, Stream/River, Perennial	11.07
55800, Artifical Path	10.74

Figure 19, continued. Water flow and water management infrastructure for Great River NWR: a) Fox Island unit, b) Long Island unit, c) Delair unit; and d-e) Clarence Cannon NWR (from Newman 2012).

and prolonged soil saturation, although relative loss of this small remnant forest area is less than most other areas in the UMRS, mainly because of the protection of the Sny Levee. In 1993, the northern 40,000 acres of the Sny Island Drainage District did flood (Olson et al. 2011).

Cannon

Cannon NWR was purchased in 1964 and part of a former agricultural levee district. Currently, most of the refuge is enclosed by levees (Fig. 17c). In 1965, over 2,600 acres of Cannon were planted for corn, soybeans, and winter wheat (unpublished refuge annual narratives). Farm acreage gradually declined on the refuge over time as lands became developed and managed for wetland habitats, however nearly 2,300 acres of soybeans, wheat, corn, and Austrian winter peas were planted on the refuge as recently as 1983. Average crop acreage on Cannon during the 2000s, except for 2008 and 2013 when most refuge lands were flooded during summer, was about 750 acres.

Starting in 1966 and continuing through the 1990s, about 2,000 acres of Cannon was developed into 27 fragmented units, usually with surrounding levees and water-control structures that enabled water management for moist-soil food production (unpublished refuge annual narratives, Figs. 18c, 19d). Much of the developed unit configuration reflected prior compartmentalization of the area by agricultural levees and ditches constructed in the 1920s and 1930s. The north-south Guinns Creek slough that historically joined Ramsey Creek was essentially leveed by construction of adjacent moist-soil units and became managed in an attempt to create a forested greentree reservoir (GTR) com-

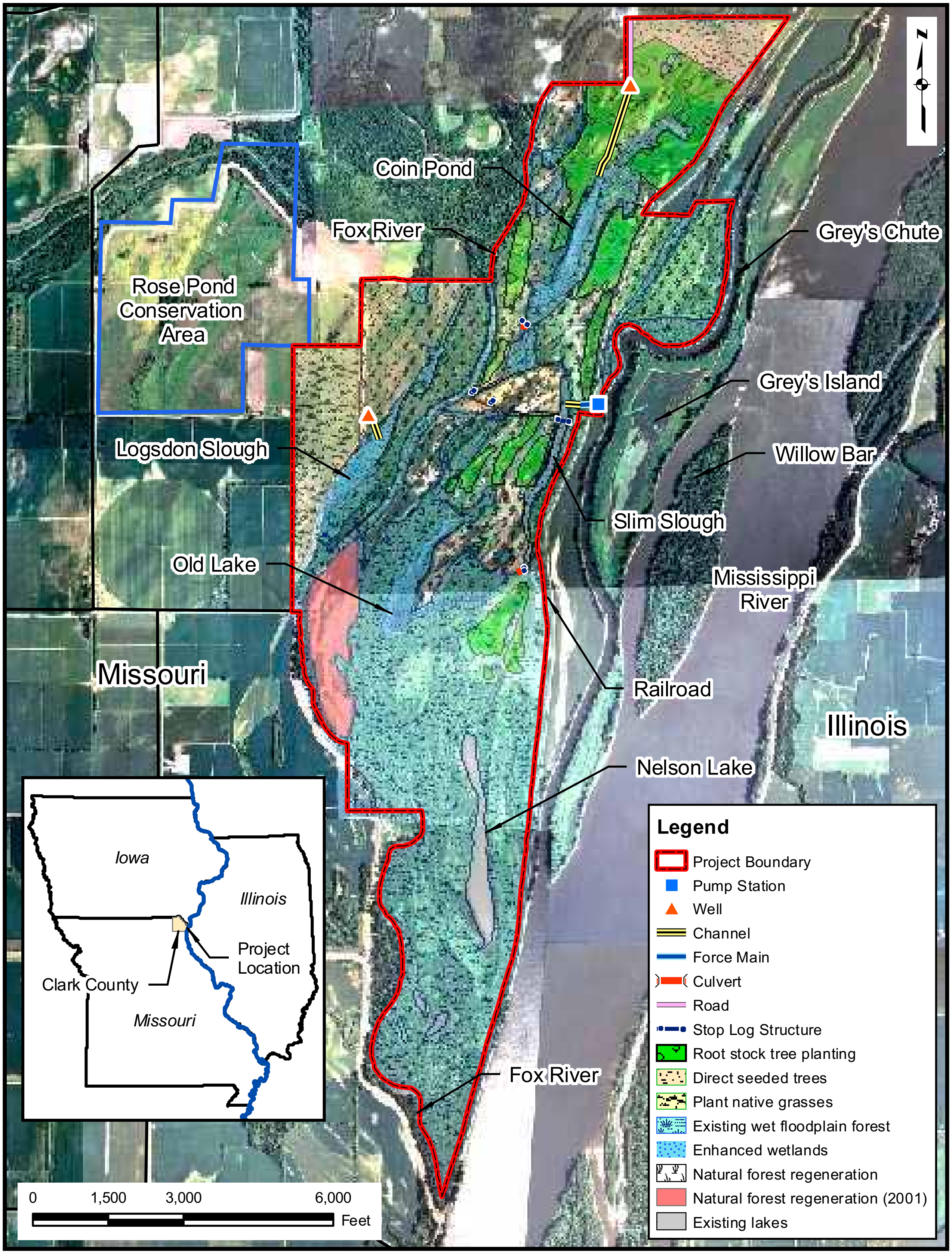


Figure 20. HREP project locations on Fox Island unit, Great River NWR (from U.S. Army Corps of Engineers 2008).

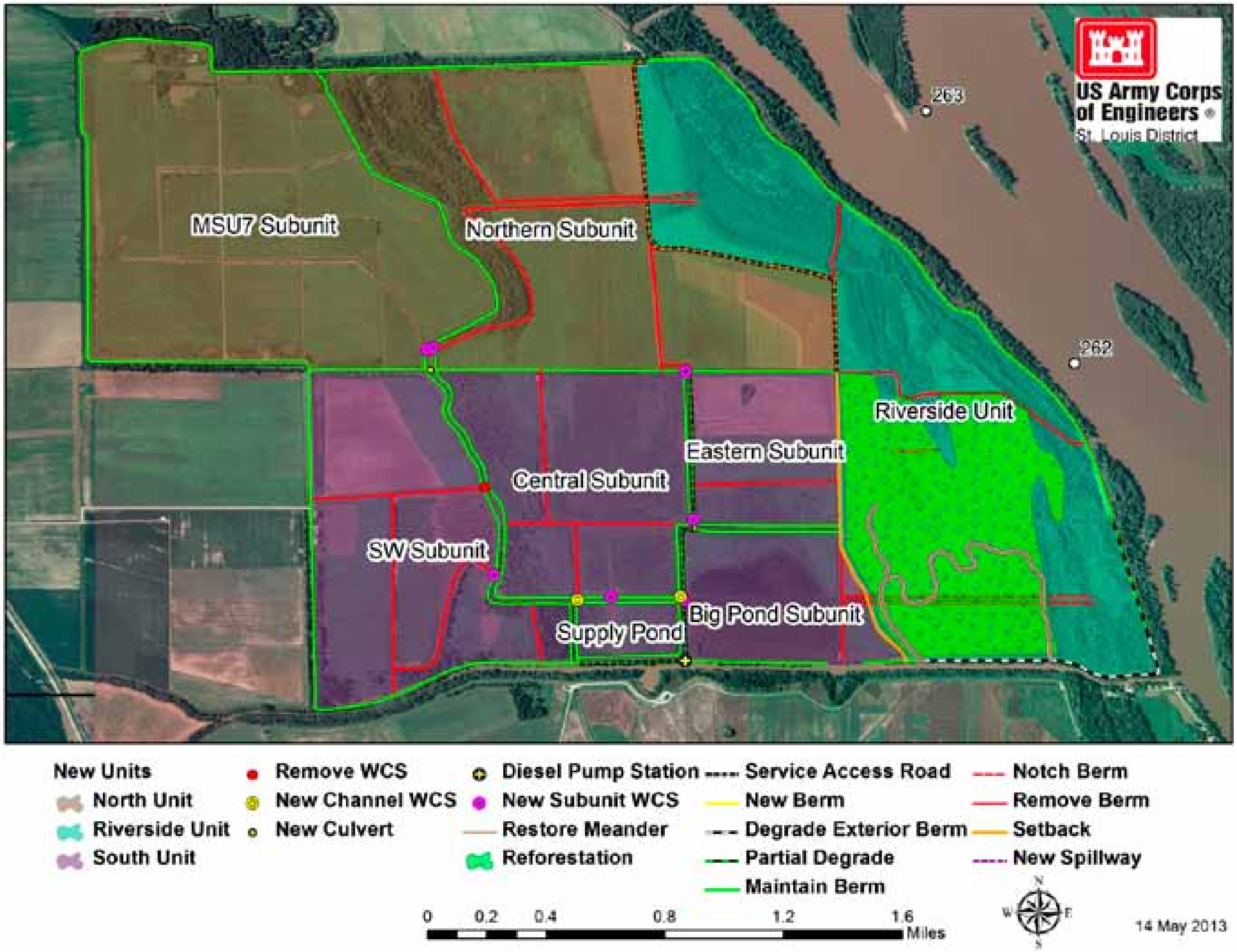


Figure 21. Proposed HREP project locations on Clarence Cannon NWR (from U.S. Army Corps of Engineers 2013).

partment, known as GTR-7 (Fig. 6). The Big Pond unit represents most of a larger natural floodplain wetland depression and the Crane Pond, Rabbit Ears, Heron Pond, Buttonbush Pond, and Rabourn Slough areas also are remnant floodplain depressional sloughs created by the historically meandering Mississippi River. Water is routed to the various wetland units by a series of ditches, which are fed by a pump station on the south side of the refuge on Bryants Creek (Fig. 19e). Over 20 water-control structures currently are present in units; the locations and types of structures have changed several times since refuge establishment.

Moist-soil units on Cannon have been managed primarily to enhance annual herbaceous plants that produce large quantities of seeds, tubers, and invertebrates used by waterfowl and other waterbirds. Water levels have been manipulated during the growing season to deter establishment of wood vegetation and promote annual herbaceous plant species. Vegetation also has been managed using several disturbance methods including alternating flooding and drying, burning, soil tillage, and rolling. Rotational farming in management units has been used to help set back succession of woody and perennial plants, control invasive species, disturb soils, and provide supplemental foods for waterfowl. Generally, physical disturbance and rotational cropping has occurred at 3-5 year intervals in moist-soil units, which have been perceived as enhancing moist-soil food production to support waterfowl, especially during fall migration.

During 2009 and 2010, MSU7 was rehabilitated and enlarged (by incorporating MSU7, WM2, and FI into a single unit) by a North American Conservation Act project that removed and modified many interior levees and ditches, reconfigured topography to emulate more natural surface features, and improve water management capabilities. This project essentially removed the fragmented subunit levee-water management design and created a larger contiguous unit. A small area in the former southwestern WM2 unit also was planted with prairie cord grass and other native grasses.

The main Mississippi River Levee on the west side of Cannon was raised from 450.2 to 452.2 feet in 1991, which was at about a 150-year flood frequency event. Following the large 1993 Mississippi River flood, an 800-foot spillway was cut into the Mississippi River levee on the southeast side of Cannon to allow water to enter the refuge during high Mississippi River stages. This increased connectivity allows high stage river water to quickly enter the refuge, however drainage back to the river typically is slow because of the levee and spillway height and the single drainage pathway at the spillway. This slow drainage tends to prolong flood inundation of much of Cannon following large Mississippi River flood events. From 1996 until 2003, river water overtopped the spillway when the Mississippi River was about 452.2 feet AMSL at the Lock-and-Dam 24 tailwater gauge at Louisiana, MO (Newman 2012). In 2004, the elevation of the spillway was raised and overtopping stage increased to 453.3 feet at the Louisiana gauge location. This spillway elevation has an approximate return interval of 20 years (Newman 2012). This spillway stage was exceeded in 2001, 2008, 2011, and 2013 and water entered the refuge several times during these events.

About 450 acres of forest was present on Cannon before the 1993 flood; most of this was early succession riverfront forest community along the Mississippi River. Prior to the 1993 flood, some pin oak, hickory, and pecan were present on higher elevations and in GTR7, however the prolonged inundation during 1993 and subsequent extended recent inundation in 2008, 2011, and 2013 has caused mortality in about 80% of 400 acres of forest present in 1993.

In 2013, a HREP project was proposed for Cannon NWR (USACE 2013). If developed, the project would help restore and improve wetlands and forest area by: 1) constructing a setback of the main Mississippi River levee with an exterior berm degrade, 2) develop three larger management units that consolidate the current fragmented unit arrangement, 3) restore historic floodplain topography and slough meander scrolls, 4) install a new diesel pump station on Bryant's Creek, and 5) reforest areas along the Mississippi River (Fig. 21).

Karen Kyle

RESTORATION AND MANAGEMENT OPTIONS

Cannon NWR and the divisions of Great River NWR represent important lands and resources that contribute to the ecological integrity of the UMRS. While none of the four tracts are large (the largest is the 6,300 acre Long Island Division), they each contain unique remnant attributes of the historical Mississippi River ecosystem and have different potential to restore communities and resources that have largely been destroyed. Two of the divisions, Long and Fox Island, are essentially non-leveed and floodplains, chutes, and side channels are directly connected to the Mississippi River during high river stages. Fox Island and Long Island are located on relatively new river bar-and-chute meander belt surfaces. As such, they contain labyrinths of recent side channels, river chutes, natural levees and floodplain ridges and swales. In contrast, Cannon and Delair are almost entirely protected by mainstem river levees and are not directly connected to the Mississippi River except during high river stages that cross the relatively new spillway location on Cannon NWR. Geomorphic surfaces at Cannon include a narrow band of bar-island scour and deposition lands immediately adjacent to the Mississippi River that includes some chute and side channel habitat, but most of the refuge is Holocene-age alluvial fill floodplain that historically contained a large contiguous area of bottomland prairie. Delair geomorphic surfaces reflect natural levees and channel fill surfaces of the relict Sny and Mississippi rivers and include a larger depressional wetland basin (Swan Lake) along with seep wetlands and some floodplain forest on higher ridges and older high elevation natural levees.

The diversity of surfaces, hydrology, and historical communities present on the four NWR divisions dictates that unique conservation strategies must be designed specifically for each area. Many studies have documented the extensive changes to the terrestrial and aquatic ecosystem components of the UMRS and several studies have analyzed HGM attributes of the ecosystem including the Cannon-Great River NWR region (e.g., USACE 1978, Bhowmik and Adams 1989, McGuiness 2000, WEST Consultants, Inc. 2000, Theiling et al. 2000, Johnson and Hagerty 2008, Heitmeyer 2010, Wiener and Sandheinrich 2010, Heitmeyer and Bartletti 2012). Ecosystem restoration and management plans for the region generally recommend that future conservation efforts for the region include attempts to restore communities and resources, especially those types that have been highly destroyed (e.g., Theiling et al. 2000, USFWS 2004). Further, conservation partners generally agree that future efforts for the UMRS include projects that can: 1) improve water quality; 2) reduce erosion, sediment, and nutrient impacts; 3) restore natural floodplain communities, 4) restore natural hydrological regimes in the river and floodplain wetlands including management to emulate seasonal flood pulses and alternately periodic low flow and dry wetland conditions; 5) restore backwater, chute, and side channel connectivity; 6) manage sediment transport and deposition in floodplains and side channels; and 7) control and discourage invasive and exotic plant and animal species.

The key to restoring native communities and their driving ecological processes at Cannon and Great River NWR, and to enhance the other above conservation goals, is identifying sites that are appropriate for, and have the best chance for sustaining, specific communities and their hydrogeomorphic processes. In other words, to design sustainable restoration programs for an individual site, it is critical to first understand what communities historically were present and whether the site still has the appropriate ecological processes that created and sustained the communities. The temptation is often to try and establish many historic communities on a site, irrespective of its historical condition, but the long term sustainability of these restored/created communities will inevitably be compromised if the site is not appropriate for the new/restored community (Heitmeyer et al. 2013).

The collective efforts to document the historical Presettlement composition and distribution of community/habitat types using GLO maps and survey notes (e.g., Yin and Nelson 1996), old maps and aerial photographs (e.g., Fig. 15 and those in Theiling et al. 2000), and now HGM analyses (Table 4, Fig. 14) provide the baseline for understanding what community types were present and their distribution and extent on Cannon and Great River NWRs. Current aerial photographs (Fig. 17) and land cover maps (Fig. 18) provide understanding of changes from the Presettlement conditions and identify areas where remnant communities are present. These data provide the template to identify areas that may be most suitable for restoring specific community types in the contemporary, highly modified, Cannon-Great River NWR environment (e.g., Heitmeyer 2008a,b; 2010; Theiling et al. 2012).

The HGM analyses in this study provide an understanding of not only where historical communities were located, but also the basic physical attributes and ecological processes that created and sustained these communities. This understanding can identify general locations that community restoration potentially could occur and be successful. Once general locations for potential community restoration are identified, then site-specific analyses can help design specific details for restoration projects at individual locations. For example, determining the potential restoration locations for floodplain forest in minor vertical accretion surfaces on Long Island will require detailed information on inundation frequency and seasonal duration (e.g., Wlosinski and Wlosinski 2001) related to elevation (e.g., Heitmeyer et al. 2009a,b).

Generally, terrestrial community restoration at Cannon and Great River NWR will necessarily be at elevations above mean water levels maintained for the 9-foot Mississippi River navigation channel. Locations below this mean water level will continue have more permanent water regimes that will cause plant communities to be aquatic/wetland types. Consequently, locations upstream of impounded areas of navigation pools, and higher surfaces such as floodplain ridges, natural levees, terraces, tributary fans/deltas, and alluvial fans and colluvial slopes offer the greatest potential for restoration sites. Main and side channels, sloughs, and floodplain lakes will continue to support open water/aquatic habitats and many actions have been proposed, and are being implemented, such as reconnection of side channels, to improve these habitats and the resources they provide to fish and wildlife species, recreational opportunities, and other ecological functions and values (e.g., UMRBC 1981, USFWS 1982, USACE 1997).

The map of potential distribution of Presettlement plant communities (Fig. 14) and accompanying matrix of relationships with HGM attributes (Table 5) identify general locations where terrestrial communities have the best potential to be maintained and restored. The combined soil, elevation and geomorphic surface data layers were highly important in predicting/identifying Presettlement community distribution and in relationship to GLO survey plant descriptions. Obviously, geomorphic surfaces also influence soils and topography on a site, and by default its general hydrological regime. Some geomorphic surfaces, such as tributary fans/deltas, tributary floodplains, and Holocene meander belts with marked ridge-and-swale topography can support more than one community (see also Heitmeyer 2008b, 2010), and for these areas more detailed site specific elevation information will be needed to delineate precise locations for specific community restoration potential.

A HGM evaluation of the Quincy, Sny, and Columbia-American Bottoms ecoregions, where Cannon NWR and much of Great River NWR divisions are located provided HGM guidance for restoration of key Mississippi River floodplain communities (Heitmeyer and Bartletti 2012). A summary of that information about most appropriate restoration sites by community type is provided below:

SHRUB/SCRUB

S/S historically was present at Cannon and Great River NWRs in narrow bands along the edges of side channels, sloughs, floodplain wetland-lakes, and tributary channels. A few very low elevation floodplain ridge-and-swale on Holocene meander belts sites also contained S/S. These sites had silty clay soils and semipermanent water regimes. Currently, higher more prolonged water regimes in navigation pools has expanded S/S into some formerly less flooded floodplain areas (such as the Riverlands Tract of Ted Shanks CA, Heitmeyer 2008a), and simultaneously eliminated much S/S in lower elevations. Restoration of S/S appears possible in these geomorphic surfaces if silt clay soils are present and water regimes can become semipermanently flooded with at least occasional drying periods during summer in some years.

PERSISTENT EMERGENT AND SEASONAL HERBACEOUS WETLAND

PEM and seasonal herbaceous wetland vegetation historically was present in a few locations on Cannon and Great River NWRs in larger bottomland lakes, swales in former river meander belts, and tributary corridors. These wetlands are dominated by annual and perennial emergent and moist-soil plants with some aquatic plants such as submersed or floating species in deeper more permanent water areas, and herbaceous species on higher edges that have more seasonal water regimes. PEM and seasonal herbaceous communities typically were on soils with silt loam and muck types that occasionally had deep organic material formed from accumulated detritus masses of decayed persistent vegetation material. These HGM characteristics remain in a few floodplain lake and floodplain depression sites such as Swan Lake and Cattail Marsh areas on Delair and Big Pond at Cannon. The key to restoring wetland/marsh habitats will be providing and sustaining semipermanent water regimes on the appropriate geomorphic surfaces and where water/soil/vegetation management can occur (e.g., Heitmeyer and Westphall 2007, Heitmeyer 2008b).

PRAIRIE AND SAVANNA

Bottomland prairie, sand prairie, and oak-savanna historically occupied areas of the Presettlement UMRS on glacial terraces, alluvial fans and colluvial slopes, high elevations on old Mississippi River natural levees, and in the confluence area of the Missouri and Mississippi Rivers. These sites typically have silt- or sandy-loam soils and were above the 5-10 year growing seasonal flood frequency elevation. Prairie-dominated surfaces were dominated by grass and forb species, while more upland areas, such as colluvial slopes, contained significant amounts of scattered oak-dominated savanna. In some areas, the GLO data suggest scattered pecan also was present in these savanna areas. Bottomland prairie was extensive at Cannon and a few sites on Delair and was dominated by prairie cordgrass and annual and perennial herbaceous vegetation. These bottomland prairies often are included in wet meadow or seasonal herbaceous marsh communities in vegetation classifications (e.g., Nelson 2005) and this HGM study did not attempt to separate the two communities. The most appropriate sites for restoration of bottomland prairie and savanna today are relict glacial terraces and higher elevations of alluvial fill and on alluvial fans/colluvial slopes (e.g., Thogmartin et al. 2010). The higher elevation terrace area on the west side of Fox Island contains Perks loamy sandy soils and likely historically supported the unique sand prairie community (Flader 1992:207). This area of Fox Island may represent one of the few remaining sites where restoration of the rare sand prairie is possible in the Upper Mississippi River System. Edges of former prairie sites, especially where they adjoin colluvial slopes, seem appropriate sites to attempt reestablishment of oak- or pecan-dominated savanna. Keys to restoring prairie and savanna will be restoring native species, providing regular disturbance from fire, or possibly grazing, and selecting sites high enough in elevation to prevent regular inundation at < 5 year frequencies.

RIVERFRONT FOREST

Riverfront forest is comprised of early succession, pioneering, tree species that are adapted to, and can tolerate regular scouring and deposition of coarse-grained river sediments. Typical riverfront forest species are willow, silver maple, cottonwood, and river birch with some shrubs, but little herbaceous ground cover. Presettlement sites in the UMRS that contained riverfront forest were main channel islands, channel lateral accretion bar, and new natural levee geomorphic surfaces. These sites contain sandy-silt soils and are flooded annually, often several times during high flow events. Regeneration of riverfront forest species requires newly scoured or deposited sandy surfaces where wind-blown seeds can settle and germinate/grow in full sunlight and non-plant competition environments. Remnant (and now increasing) riverfront forest areas are present on all four Cannon and Great River NWR areas. Unfortunately, many of these riverfront forest sites have shifted to nearly monocultures of silver maple and willow (e.g., Nelson and Sparks 1998, Fig. 16). Wind and wave action in lower parts of navigation pools often prohibits establishment of riverfront forest, mainly because the island is actively being eroded and eliminated. Most larger islands in the Cannon-Great River region retain the capability to sustain riverfront forest, but generally the active process of repetitive scouring and deposition on lateral accretion and island surfaces is now absent or greatly reduced because alternating high flow flood events with scouring action and alternating low flow periods when cottonwood and sycamore can become established are absent or greatly attenuated by water management of navigation pools. Riverfront forest can be restored on lateral accretion surfaces and some larger islands, but restoring a greater diversity, especially regeneration of cottonwood probably will require more intensive management to provide regularly scoured and/or deposited sandy materials on these sites.

FLOODPLAIN FOREST

Floodplain forest habitats historically were present on higher elevation (> 2-year flood frequency zones) ridges and natural levees at Cannon and Great River NWR and provided important resources to many animal species and also contributed vital functions and values to the entire UMRS ecosystem. This community occupied several geomorphic surfaces where silt loam and silt clay soils were present and flooding regimes were > 2-year growing seasonal flood frequency and with extended drying periods during summer and early fall. The diversity of species in floodplain forest was maintained by slight elevation and hydrology differences and the periodic drying of the sites. Floodplain forests have been highly destroyed throughout the UMRS, and on all Cannon-Great River NWR tracts, because of wetter water regimes caused by navigation pool management and the recent extensive and prolonged growing season floods of 1993, 2008, 2011, and 2013. Remnant floodplain forests at Cannon-Great River NWR now generally are small, highly fragmented, have reduced species diversity, and include wetter-type species, that often are subject to disease (e.g., Dutch elm and emerald ash borer mortality of elm and ash trees). Restoration of floodplain forest should target appropriate higher elevation sites on tributary fans/deltas, old meander belt, natural levees, colluvial slopes, and select low swale sites (e.g., Heitmeyer and Bartletti 2012). These restoration sites must have silt loam and silt clay soils and be at elevations where regular summer-early fall drying can occur. The species composition of restored floodplain forests probably will continue to be dominated by slightly more water tolerant species such as American elm, green ash, box elder, and interspersed cottonwood, river birch, and willow. Pin, bur, and swamp white oak and native pecan historically was present in higher elevations of floodplain forest areas at Cannon and Great River NWRs; their distribution appears to have been restricted to elevations with > 2-5 year growing season flood frequency and regular extended periods of drying in summer. Consequently, restoring and expanding oak and pecan in floodplain forests at Cannon and Great River NWRs will need to carefully evaluate elevations and flooding regimes and target plantings of these species to the very highest elevations in former floodplain forest locations/geomorphic surfaces

BOTTOMLAND HARDWOOD FOREST

BLH historically covered small areas on Delair and Fox Island on higher elevation tributary fans and tributary channel belts where annual flooding was for short durations in winter and spring and at > 5-year growing season recurrence intervals. The largest extent of BLH on the refuges occurred on the old Yazoo Meander Belt geomorphic surface that contains the Sny River drainage. Only a few other locations along the Mississippi River north of St. Louis historically contained "true" oak-dominated BLH; these were present on the Salt River tributary fan on the south end of the Ted Shanks CA and on higher ridges of the Illinois-Mississippi River confluence area at Calhoun Point CA (Yeager 1949, Nelson and Sparks 1998, Korschgen and Toney 1976, Heitmeyer 2008a). Scattered BLH also occurred above the Fabius River near Hannibal and along the Cuivre River in Missouri.

SPECIFIC ECOSYSTEM RESTORATION AND MANAGEMENT RECOMMENDATIONS FOR CANNON NWR AND GREAT RIVER NWR DIVISIONS

Specific habitat management actions for Cannon and Great River NWR divisions were identified in the 2004 CCP for the Mark Twain NWR Complex (USFWS). More recently, the now nearly completed HREP at Fox Island and the proposed HREP for Cannon identified habitat restoration and management projects (USACE 2008, 2013). And, in 2012, a Habitat Management Plan (HMP) was prepared for Cannon and Great River NWR (USFWS 2012). Each of these planning documents provided important analyses and discussion of benefits and values of many conservation actions and projects. Fortunately, much HGM information was included in formulating these conservation plans. This HGM evaluation adds to these previous plans and helps advance understanding about appropriate sites for restoration and the management that will be necessary to sustain communities, resources, and ecological processes. The HGM information also identifies actions that help address the primary ecosystem changes and problems in the Cannon-Great River NWR area, which are:

- Reduced or eliminated river-floodplain connectivity.
- Loss of native plant communities, especially bottomland prairie and floodplain and BLH forest types.
- Habitat fragmentation.
- Loss of floodplain topographic features and slough, chute, and side channel habitats.
- Altered water regimes and hydrology.
- Spread of invasive and exotic species.

Specific recommendations based on this HGM analyses are provided below for each area.

Fox Island

The Fox Island Division contains a diverse complex of habitat types and communities at the confluence of the Fox and Mississippi rivers. Much of the area is relatively new river island/bar and chute surfaces. Interior sloughs and chutes, along with remnant side channels, reflect recent movement and abandonment of former channels of the Mississippi (and to some degree the Fox River also) River. Consequently, Fox Island is highly connected to the Fox and Mississippi rivers during high river stages and most floodplain sites historically were seasonally flooded during spring and early summer. As river stages fell in summer and fall, water in chutes and sloughs receded and forest areas dried. This pattern of seasonal connectivity and spring flooding has largely been maintained because the mainstem river levee in on the far west side of the area and allows Mississippi River water to enter and recede from the site based on stage height . The marked heterogeneity of topography resulting from the alternating depositional ridge and scoured swales and chutes created high interspersion of community types that mostly were forested (Fig. 14). The far northwest side of the Fox Island Division also contains an older terrace upland where prairie and perhaps savanna merged with floodplain forests and wetlands. The HGM map of potential historical communities reflects the heterogeneity of soils, elevations, and hydrology and can be a guide for restoration. Specific restoration actions that seem appropriate for Fox Island include:

- Restore sand prairie/savanna on the far west part of the area behind the mainstem levee on Perks soils.
- Plant and restore oak and pecan on the highest floodplain elevations that contain Colo soils. These sites have the highest probability of survival of the less water tolerant oak and pecan species because they will be flooded for the shortest periods during high river stage events.
- Restore diverse floodplain forest species composition on higher elevations that contain Beaucoup, Fatima, and Huntsville soils.
- Maintain riverfront forest on areas adjacent to rivers and sloughs/chutes with Gifford, Klum, and Wakeland soils.
- Encourage S/S habitats along sloughs and wetland depressions where Zook soils are present.
- Maintain connectivity of all chutes, sloughs, and side channels with higher stages of the Mississippi River. This may require removal of debris or excessive sediment obstructions and removal or modification of levees, berms, ditches, roads, and water-control structures that block or impeded interconnected flows during high river stages.
- Manage new HREP water-control structures to emulate natural patterns of spring and early summer flooding, summer drawdown, and then low levels in fall and winter in wetlands and sloughs. Further, evaluate all HREP structures to determine how and if they allow high stages of the Mississippi and Fox rivers to back water into, or create side channel flows, through the area.

Long Island

The Long Island Division is a young river island-floodplain surface created by recent meandering and channel separation of the Mississippi River. The site is not leveed and historically high Mississippi River stages caused water to flow through all remnant chutes, sloughs, and side channels and to seasonally flood most, if not all, floodplain surfaces, which were predominantly forested. Sedimentation and debris accumulation has reduced river connectivity and active flows through the area, but high river stages still flow through and inundate most of the area. The forest block on Long Island is the largest contiguous forest tract along the Mississippi River from Rock Island to Cairo. In the past some clearing of this forest tract occurred in an attempt to farm some higher elevations. More consistent and higher water levels caused by management of Lock-and-Dam 21 has shifted forest composition on Long Island from a diverse floodplain forest composition to one that currently is dominated by early succession silver maple and willow. Old attempts to create a few small moist-soil impoundments on the Division failed and water-control structures have not been replaced or repaired.

Historically, Long Island contained riverfront species on annually flooded newly accreted soils, floodplain forest on higher elevation, and older silt loams where growing season flooding was of shorter duration and > 2-year recurrences. The many side channels and river chutes provided interconnected water and river flows that sustained important fishery and aquatic communities. Consequently, long-term management of Long Island should seek to maintain these communities and processes. Specific restoration actions include:

- Maintain forest on floodplain lands on the Division and do not develop new water-control or moist-soil impoundment infrastructure.
- Cooperate with the USACE to maintain and restore a more diverse floodplain forest community on higher elevations where flood frequencies are > 2 to 5-year return intervals. A systematic inventory of forest species related to elevations and flood frequencies on the Division is needed to determine where less water tolerant trees such as oak, elm, ash, pecan, and sugarberry can survive and be managed for.
- Conduct management prescriptions currently identified in the USACE Forest Management Plan for the division (USACE 2012). Specific desired actions include stratified tree plantings that place trees in locations that match their water tolerance (see above recommendation), careful timber stand improvement work, and invasive species control.
- Maintain the bathymetry of side channels, sloughs, and chutes so that higher stages of Mississippi River flows can enter, flow through, and exit these areas and also provide widely distributed flood pulsing into floodplain areas. Maintenance of these channel/chute areas may require removal of some sediment or debris obstructions and or any older infrastructure. Sites of special interest include the LaGrange, Smoot, O'Dell, and Canton chutes. Management suggestions for these chutes in the refuge HMP (USFWS 2012) should be conducted.

Delair

Historically, the Delair Division contained a diverse array of communities including small areas of bottomland prairie, BLH on higher elevation natural levees and ridges, floodplain forest on alluvial sites, riverfront forest next to the Mississippi River, and S/S and PEM/seasonal herbaceous marsh in remnant depressions and the Swan Lake complex. The Division now is entirely protected by the Sny Levee and surface waters from the Mississippi River are disconnected from the area. Interestingly, considerable groundwater connection from the river to some floodplain depressions, such as the Cattail Marsh area, occurs because of the sandy substrata of soils. Especially during high river stages, water seeps into these wetlands and creates extended saturated or shallowly inundated areas.

The disconnected and artificial nature of Delair, makes true restoration of historical setting and community distribution impossible at the current time. Nonetheless, several important restoration and management opportunities exist including:

- Evaluate the potential to restore small areas of bottomland prairie on Petrolia, Coffeen, and Ceresco soil locations.
- Restore floodplain forest on Titus and Wakeland soil locations.

- Restore BLH on Darwin and Beaucoup soils, except in seepage areas, which are better suited for wet prairie and moist-soil habitats
- Maintain riverfront forest on Ambraw, Zumbro, and Sarpy sandy soils.
- Manage the Swan Lake complex as a connected PEM/seasonal herbaceous floodplain lake-marsh site. Modify existing water-control infrastructure to allow Swan Lake to be connected with the slough area in Cattail Marsh and create a more natural PEM/seasonal herbaceous wetland complex.
- Manage other wetland areas as independent units that can replicate natural seasonal and long-term patterns of flooding and drying. This management will require improvements in existing water-control infrastructure to create more independent water management among the wetlands. For example, the Cattail Marsh complex is subject to seepage from high stages of the Mississippi River and will naturally have a longer and more dynamic flooding regime than for example the Hanei marshes. Consequently, Cattail Marsh will tend to have more semipermanent flooding and PEM type communities compared to shorter duration moist-soil habitats in other areas.
- Manage moist-soil units to create diverse seasonal herbaceous communities using water management and physical disturbances including fire, tillage, rolling, mowing, and rotational agricultural cropping.
- Control invasive and undesirable vegetation such as RCG using a combination of chemical and physical manipulation.

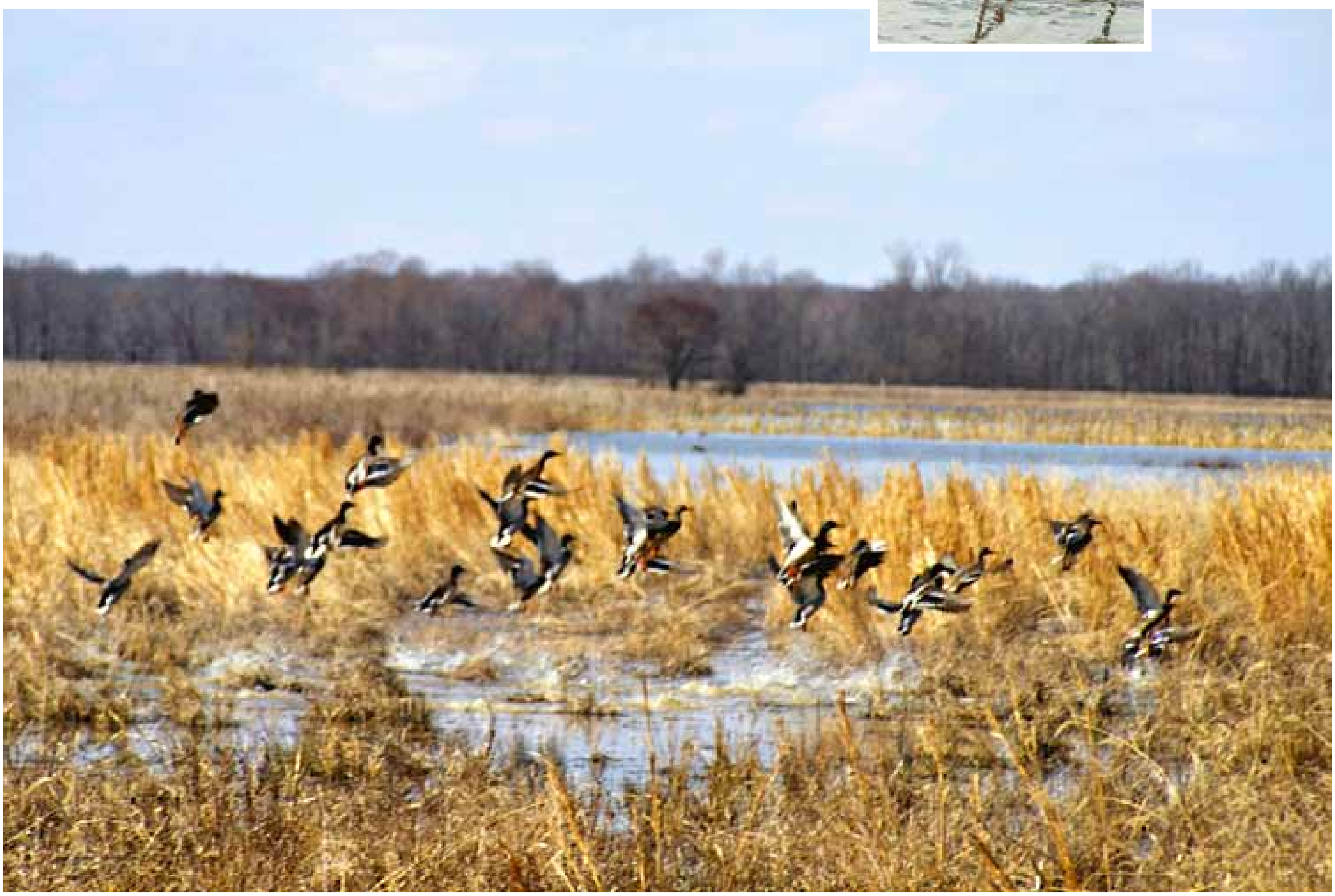
Cannon

Lands within Cannon NWR historically contained a large contiguous area of bottomland prairie on older alluvial deposits and a narrow band of mainly riverfront forest along the Mississippi River (Fig. 14). River chute and slough areas occurred near the river where former channels and scour areas occurred. A relatively large floodplain wetland depression was present at the Big Pond area and smaller remnant depressions occurred at Crane Pond, Rabbitears Slough, and Rabourn Slough. A small area of prairie-savanna may have been present on the bottom end of a colluvial fan in the far west part of the area. Most of the extensive bottomland prairie area was leveled, ditched, and leveed for agriculture in the 1920s and 1930s and most of the refuge area was enclosed by levees to protect farm lands. After the USFWS acquired Cannon, the interior areas were extensively developed and managed for moist-soil and agricultural habitats. More recent developments have sought to establish some reconnection of the site with high stages of the Mississippi River, restore site-specific topography, and maintain productive mosaics of herbaceous wetland habitats. These developments and those proposed by the 2013 HREP for the refuge (USACE 2013) are mostly consistent with the HGM evaluation in this report. Collectively, the HREP and HGM evaluations suggest that future restoration of Cannon NR should seek to:

- Restore a prairie-savanna community on the high elevations with Dupo and Moniteau soils.
- Restore diverse floodplain forest communities on Blackoar and Klum soil areas.
- Maintain riverfront forest adjacent to the Mississippi River on Dockery soils.
- Reconfigure the existing wetland units to: 1) enlarge units; 2) restore natural topographic features such as historic meander scrolls, ridges, and swales; and 3) enable water management to maintain more natural mosaics of seasonal herbaceous and bottomland prairie habitats. Some reconfiguration will require changes to existing water-control and supply infrastructure such as outlined in the 2013 HREP proposal. Where possible wetter regimes that encourage a more natural wet prairie/marsh community should be developed on Carlow soils and drier regime moist-soil habitats should attempt to align with Chequest and Twomile soils.
- Manage slough and natural wetland depression areas for semipermanent PEM/herbaceous/S/S habitats. Specifically, attempt to restore the Big Pond area to its larger, undivided, configuration and manage it for seasonally and interannual dynamic natural water regimes.

- Manage vegetation in restored prairie and herbaceous wetland units to sustain productive assemblages of species using dynamic water management, tillage, mowing and rolling, periodic fire, and rotational agricultural cropping.
- Increase river-floodplain connectivity by constructing the levee setback and exterior berm degrade features proposed in the HREP.

Cary Aloia



Karen Kyle

MONITORING AND EVALUATION

The current understanding of the Cannon-Great River NWR ecosystem has been greatly enhanced by documentation of system attributes and management actions (such as in former annual narratives of the refuge) and past monitoring and evaluation studies of vegetation and animal communities, water quality and quantity, and specific management actions. Future management of the system should incorporate key monitoring studies and direct research as needed (Paveglio and Taylor 2010). Monitoring will be determined primarily by refuge objectives, but some measures should be collected that indicate how factors related to ecosystem structure and function are changing, regardless of whether the restoration and management options identified in this report are undertaken. Ultimately, the success in restoring and sustaining communities and ecosystem functions and values at Cannon and Great River NWRs will depend on how well the physical integrity and hydrological processes and events within the refuge can be restored, maintained, and emulated by management actions as well as the relative resiliency of different habitat types. Therefore, monitoring and evaluation of the management strategies employed at Cannon and Great River NWR must be long enough to account for the spatial and temporal rate of change for different abiotic and biotic characteristics that are altered (Michener and Haeuber 1998).

Whatever future management actions occur on Cannon and Great River NWR, activities should be done in an adaptive management framework where: 1) predictions about community response and water issues are made (e.g., decreased invasive weed dominated habitats) relative to specific management actions (e.g., restoration of seasonal sheetwater flow) in specific locations or communities, and 2) follow-up monitoring is conducted to evaluate ecosystem responses to the action. Recently, an inventory and monitoring plan for Cannon and Great River NWRs was developed (Hanan 2013). This plan identified survey and study needs for various animal species, especially waterbirds; forest, grassland and wetland communities; and topographic information. These inventory and monitoring needs are important; other needs related to the hydrogeomorphic information evaluated in this report are identified below:

GROUND AND SURFACE WATER QUALITY AND QUANTITY

The recent WRIA for Cannon and Great River NWRs (Newman 2012) identified several important future monitoring and information needs related to water. These and other needs include:

- Initiate a recurrent water monitoring program to document long-term changes in surface and groundwater quality and quantity.
- Conduct routine monitoring of water quality and contaminant issues in relation to water source and routing. Regular monitoring of surface, ground, and soil salinity in key reference locations related to HGM-determined communities should be established.

RESTORING NATURAL WATER FLOW PATTERNS, AND WATER REGIMES

This report identifies several potential physical and management changes that could help restore natural topography, water flow, and flooding/drying dynamics in managed wetlands. These changes include restoring sheetflow through natural drainages across the floodplain, improving river-floodplain connectivity, and managing impoundments (that are retained) for more natural flooded seasonal flooding regimes. Further, restoring interannual dynamics of flooding and partial drying of the impoundments managed for seasonal and semi-permanent water regimes and persistent emergent vegetation is desired. The following monitoring will be important to understanding effects of these changes if implemented:

- Evaluate current water-control infrastructure to determine if current and future water management needs (e.g. capacity and placement) are being met or if changes to the system are warranted.
- Evaluate current hydrologic flow patterns, including river connections during high stages to the Cannon floodplain and chute-side channel complexes at Fox and Long Islands in relation to HGM recommendations to restore some historical flow through natural channels
- Evaluate surface and groundwater interactions and flow, especially at Delair where river seep water is common.
- Document and monitor timing, duration, and extent of surface water across habitat types. Observations of how water flows through current water-control structures in, for example, reconfigured and enlarged wetland units and restored bottomland prairie habitats will help guide the modification of existing structures and the placement of new ones in appropriate locations, both vertically and horizontally, to distribute water in a sheetflow pattern without causing head-cuts or other water delivery-induced impacts to the system (Zeedyk 1996).

LONG-TERM CHANGES IN VEGETATION AND ANIMAL COMMUNITIES

The availability of historic vegetation information coupled with regularly documenting changes in general and specific vegetation communities is extremely important to understand the long-term changes and management effects on Cannon and Great River NWRs. Also, regular monitoring of at least some select animal species or groups helps define the capability of the ecosystem to supply key resources to, and meet annual cycle requirement of, animals that use the refuge and regional area. Many important survey/monitoring needs are provided in Hanan (2013) and others include:

- Mapping the cover, density, and diversity of invasive species over time in relation to management strategies.
- Success of forest restoration and natural regeneration, especially where floodplain forest and BLH is desired.
- Changes in extent of different wetland and upland habitats as hydrologic changes occur in relation to timing, duration, periodicity, and source of water resources utilized
- Occurrence, timing, and habitat use of key migratory and breeding birds, including Neotropical songbirds, secretive marsh birds, waterfowl, and colonial waterbirds.
- Vegetation response to mechanical manipulations mimicking natural processes such as scouring events, burning, rolling, and tillage.
- Occurrence, distribution, and abundance of amphibians and reptiles in relation to different hydrologic regimes, wetland types, and management strategies.
- Occurrence, distribution, and abundance of invertebrates in relation to different hydrologic regimes, wetland types, and management strategies.

ACKNOWLEDGEMENTS

This project was supported by Contract No. F10PD77256 between the USFWS and Blue Heron Conservation Design and Printing LLC. Jason Wilson, Project Leader and staff of Cannon and Great River NWRs sponsored the project and assisted with all field visits, planning meetings, gathering of information for the refuge, and review of draft reports. Candy Chambers provided much background information and insight on historical management of refuge units. Mick Hanan assisted with collation of all data and provided drafts of the 2013 Inventory and Monitoring document for the refuge. Pat Heglund, USFWS Regional Biologist, helped initiate the project and provided administrative support and review of the project. Josh Eash and Vince Capeder, USFWS regional hydrologists, assisted with preparation of the WRIA and other water resource items used in the report. Karen Kyle, Blue Heron Conservation Design and Printing LLC, administered the contract for the project and provided assistance with analyses of data and geographical information, preparation of maps and report drafts, and publication of the final report.

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